SEWAGE WORKS JOURNAL

VOL. XII MARCH, 1940 No. 2

Special Articles

Annual Report of Research Committee

Flocculation Without Chemicals—Fischer

Progress in Chlorination—Griffin, Faber, Klegerman

Treatment of Winery Wastes—Hodgson

OFFICIAL PUBLICATION OF THE
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SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

A Bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of sewage works.

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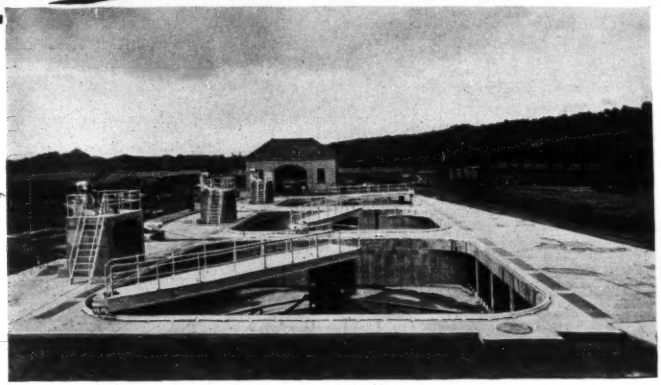
Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879.

IT PAYS TO WASH GRIT *to a*



Three Dorr Detritors at Back River Plant, Baltimore, Md.—Capacity 300 M.G.D.
Cons. Engrs.: Whitman, Requardt & Smith, Baltimore

SPECIFICATION *with* DORR DETRITORS

WHAT DORR DETRITORS DO

1. Remove all grit coarser than 65 mesh (or 100 mesh if you so specify).
2. Deliver a drained and washed grit containing not more than 3 per cent by weight of putrescible organics.
3. Make same removals and washings at all rates of flow—maximum, design and minimum—without adjustment.
4. Designed hydraulically to operate at minimum loss of head.
5. Structurally and mechanically designed to preclude odors, unsightliness or septic action.

DORR DETRITORS are not designed on the old rule of thumb formula—"1 ft. per sec. velocity at maximum flow and 60 secs. detention". Research and field studies show that area, plus positive mechanical removal, are the governing factors, regardless of feed composition or range of flow.

Simple collection of detritus as provided in a number of units of various types and shapes is hardly enough. Complete collection of detritus *plus washing* to the specification at left can only be accomplished in a Dorr Detritor.

Proper removal of sewage grit means an end of plugged pipes and valves, worn pumps and machines and deposits in tanks, filter beds and aeration channels. Clean grit, free from putrescibles, means an easy disposal job, free from odors and unsightly conditions.

DORRCO

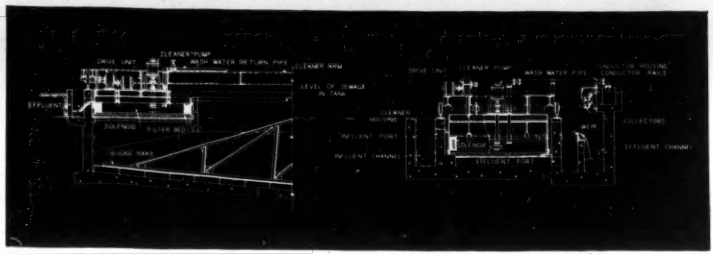
Write for a complete technical reprint on design factors in grit removal and washing

THE DORR COMPANY, INC. • ENGINEERS

570 LEXINGTON AVE. • NEW YORK

ATLANTA • TORONTO • CHICAGO • DENVER • LOS ANGELES

THE AUTOMATIC MAGNETITE FILTER



LEFT: Upflow Filter in circular settling tank. RIGHT: Downflow Filter in separate structure.

WHAT IT IS *and* WHAT IT DOES

Let us summarize here what has been brought out in our previous ads this year in SEWAGE WORKS JOURNAL.

▶ WHAT IT IS

The Automatic Magnetite Filter is a strainer for removing suspended solids from the effluents of primary and secondary settling tanks. Two types are available—the upward and downward flow types—both of which may be installed either as integral parts of the settling tanks or else in separate structures.

▶ WHAT IT DOES

It gives uniformly good effluents regardless of variations in the volume and character of the influent. It does this at a lower cost per ton of solids removed than any other method operating over the same range.

TO BE SPECIFIC —

IN PLAIN SEDIMENTATION—Less settling capacity required and an effluent improved 40 per cent. Settling for 2 hrs. plus magnetite filtration yields an 80 per cent removal and 15 to 25 per cent less chlorine consumption.

IN CHEMICAL PRECIPITATION—50 per cent less chemical consumption—less time for coagulation and settling—a better final effluent.

IN ACTIVATED SLUDGE—Less settling and aeration tank capacity—less compressed air—a better final effluent.

IN TRICKLING FILTERS—If installed ahead of filters, less primary settling tank capacity and less solids on filters. If behind, less humus tank capacity, less final, unsettleable solids and a better effluent.

Better write for The Automatic Magnetite Filter Bulletin

THE AUTOMATIC MAGNETITE FILTER IS MARKETED EXCLUSIVELY BY THE DORR COMPANY, INC.

FILTRATION EQUIPMENT CORP.

10 East 40th Street Sales Office New York, N. Y.

COARSE SCREENS · AUTOMATIC MAGNETITE FILTERS · CONKEY VACUUM FILTERS

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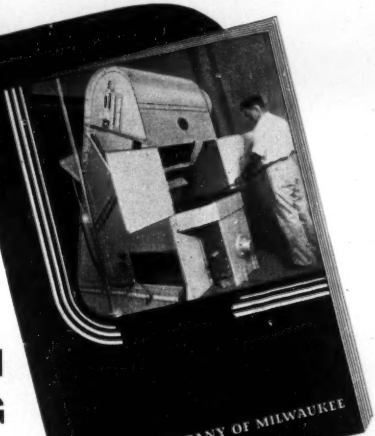


CHAIN BELT COMPANY OF MILWAUKEE

SEND FOR YOUR COPY OF THIS NEW BOOK!

YOUR PROBLEM IS SCREENING SEWAGE OR SHREDDING SCREENINGS...

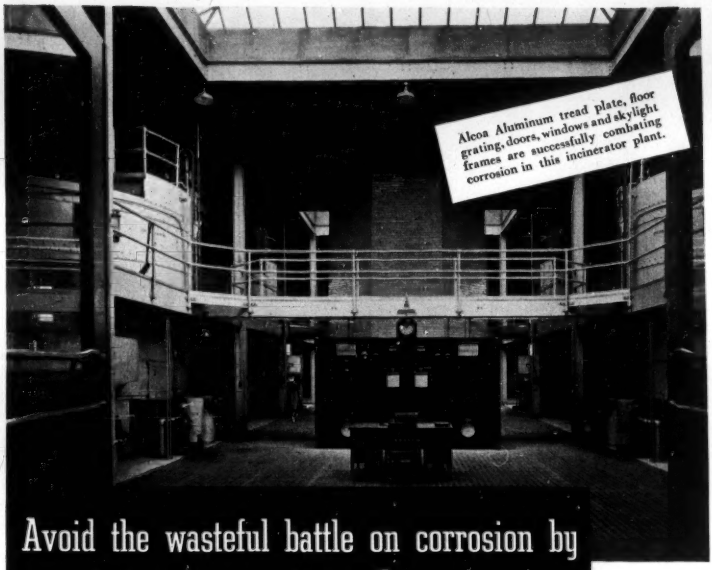
Sanitary engineers! Sewage plant operators! Anyone who is responsible for the efficient screening and disposal of municipal or industrial sewage should have a copy of this new book which describes Rex Mechanically Cleaned Bar Screens and Rex Triturators! Complete with detailed design data and application information, it is a valuable reference book to keep in your files.

Bulletin 319 also contains reprints of two articles written by experienced sanitary engineers. They describe in detail the benefits of using Rex Triturators and Rex Mechanically Cleaned Bar Screens in their plants.

Whether you're modernizing an old plant or building a new one, you need this fund of information close at hand. Send for your copy now! Address Sanitation Equipment Division, Chain Belt Company, 1606 W. Bruce St., Milwaukee, Wisconsin.

REX CHAIN BELT COMPANY OF MILWAUKEE

SANITATION EQUIPMENT


Alcoa Aluminum tread plate, floor grating, doors, windows and skylight frames are successfully combating corrosion in this incinerator plant.

Avoid the wasteful battle on corrosion by *Building with Aluminum*

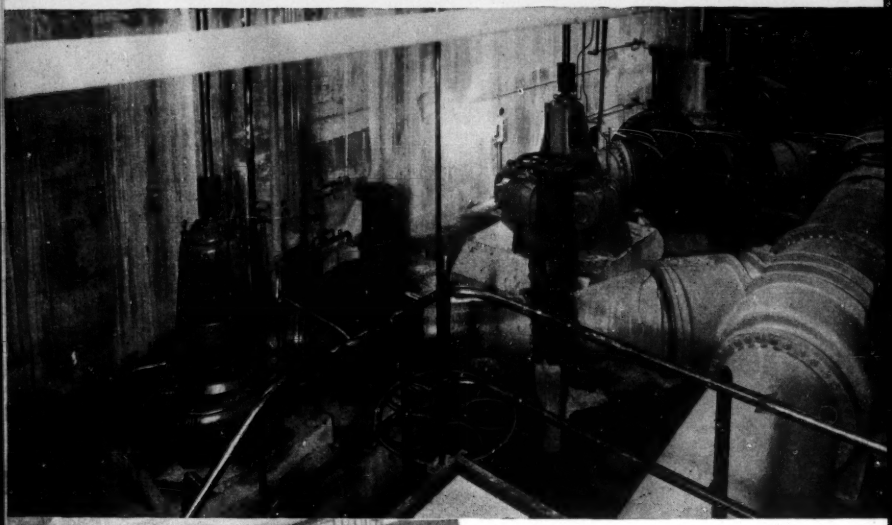
Ordinary metals, unprotected, don't last long in many locations in a sewage disposal plant. True their life can be lengthened by painting, but *this costs money*. And there are many hidden corners which can't be given adequate protection. Corrosion soon gains a foothold there.

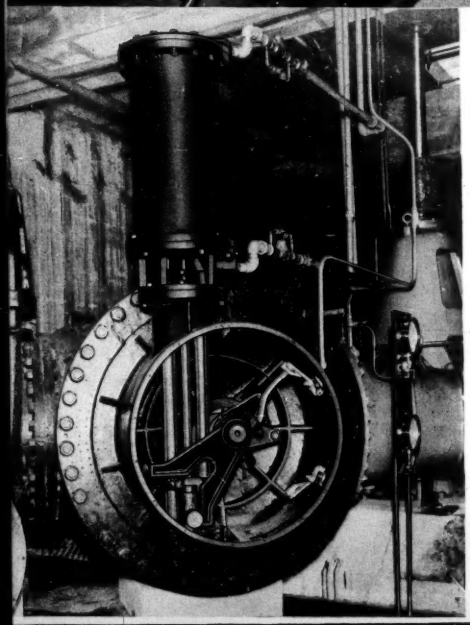
You don't have to provide this protection where Aluminum is used, so operating costs are less. In this sewage incinerator plant, for example, the Aluminum floor grating will retain its original high strength; the Aluminum doors, windows and skylight frames are here to stay. Mighty little attention is needed to keep Aluminum construction safe and looking fine.

For equipment that must be painted, use Aluminum paint, now standard in many sewage disposal plants. You'll get longer life with this "coat of metal protection." And for best results, specify paint made with Alcoa Albron pigment. ALUMINUM COMPANY OF AMERICA, 2111 Gulf Building, Pittsburgh, Pennsylvania.

ALCOA ALUMINUM

The Ideal Check and Control





View at Tallman's Island Sewage Treatment Works, New York, Showing 36" and 20" Chapman Automatic Cone Valves used as Discharge Checks for Screened Sewage Pumps.

(*At left*)
One of above Chapman Cone Valves with Cover removed, showing Valve Operating Mechanism.

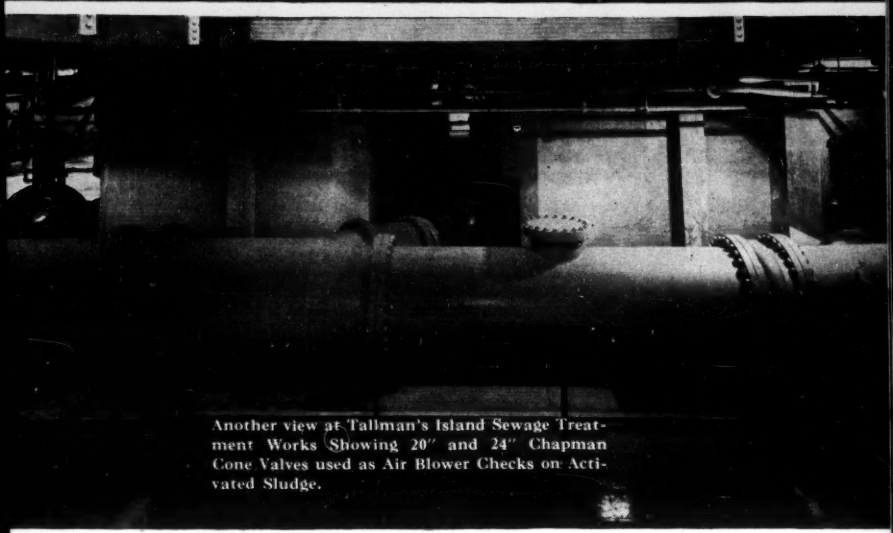
TYPICAL USES
CHAPMAN CONE VALVES
IN SEWAGE TREATMENT WORKS

1. Sewage Pump Discharge Check Valves.
2. Control of Sludge Chamber Levels.
3. Quick Operating Valves for Grit Chambers.
4. Air Blower Check Valves on Activated Sludge.

THE CHAPMAN VALVE

INDIAN ORCHARD,

For Sewage Treatment Lines



Another view at Tallman's Island Sewage Treatment Works Showing 20" and 24" Chapman Cone Valves used as Air Blower Checks on Activated Sludge.

Chapman

AUTOMATIC CONE VALVES

There are good reasons for the widespread use of Chapman Cone Valves in sewage treatment work. The valve itself is simple and extremely efficient. Its operation is positive and ingenious. Its ideal qualities for handling sewage are fully demonstrated.

Here are some of the reasons why:

Smooth pipeline waterway—no place for sewage to lodge.

Seats not in contact with sewage in open position.

Positive shutoff—valve is actuated by power independent of the sewage line.

Tight shutoff—rotary action of plug prevents material from lodging between seats in closing.

No slam or rattle—valve not actuated by sewage flow.

Special controls available for any specific condition.

List of installations supplied on request.

MANUFACTURING CO.

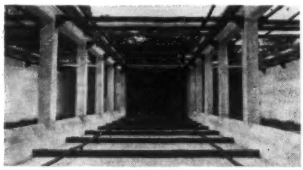
MASSACHUSETTS

STRAIGHTLINE COLLECTORS

for Best Results with the

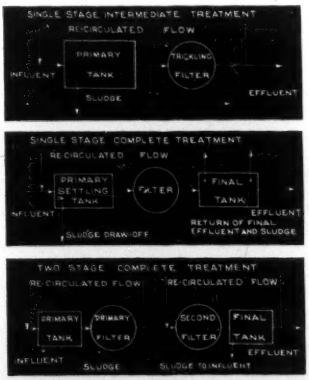
BIOFILTRATION SEWAGE TREATMENT SYSTEM

● Much of the effectiveness of this system depends on the reactions between the filter effluent and the raw or partly treated sewage in the settling tanks.
Rectangular tanks equipped with Link-Belt STRAIGHTLINE Collectors have proved ideal for this process; giving excellent results wherever used. The California plants listed on this page employ the Biofiltration system, with STRAIGHTLINE Collectors.



Camarillo, Calif.

This is a complete Biofiltration plant. The two primary tanks, each of which is 10′ 0″ wide x 10′ 0″ water depth x 54′ 0″ long, are equipped with STRAIGHTLINE Collectors. The secondary tank is also equipped with two STRAIGHTLINE Collectors, each 18′ 0″ wide x 10′ 0″ water depth x 54′ 0″ long.



San Mateo, Calif.

The large city plant for the treatment of the entire volume of sewage is of the separate sludge digestion type. A small volume of treated sewage from the settling tank flows to a small Biofiltration plant which was installed for the purpose of purifying a sufficient amount of sewage for use in irrigation and as wash water around the plant. The two settling tanks, each of which are 6′ 0″ wide and 3′ 0″ water depth x 15′ 0″ long, are equipped with Link-Belt STRAIGHTLINE Collectors.

Placerville, Calif.

This is a complete Biofiltration plant, equipped with two STRAIGHTLINE sludge collectors for the final settling tank. Each is 16′ 0″ wide x 12′ 0″ water depth x 58′ 0″ long.

Turlock, Calif.

This complete Biofiltration plant employs one STRAIGHTLINE sludge collector for the primary tank—18′ 0″ wide x 12′ 0″ water depth x 68′ 0″ long—and two STRAIGHTLINE longitudinal sludge collectors and one cross collector for the final tank—37′ 0″ wide x 12′ 0″ water depth x 68′ 0″ long.

Lakeport, Calif.

A complete Biofiltration plant with one STRAIGHTLINE Collector for the primary tank—10′ 0″ wide x 8′ 0″ water depth x 32′ 4″ long, and one STRAIGHTLINE Collector for the final tank—10′ 6″ wide x 8′ 0″ water depth x 32′ 4″ long.

San Leandro, Calif.

While this is not a complete Biofiltration plant, it does use a small biofilter unit for the same purpose as at San Mateo, previously described. It employs three STRAIGHTLINE Collectors for the final tank, each measuring 7′ 0″ wide x 4′ 0″ water depth x 20′ 0″ long.

Yountville, Calif.

This plant, which will be of the Biofiltration type, employs one STRAIGHTLINE sludge collector for the primary tank—15′ 0″ wide x 10′ 0″ water depth x 62′ 0″ long, and one STRAIGHTLINE Collector for the secondary tank—15′ 0″ wide x 10′ 0″ water depth x 62′ 0″ long.

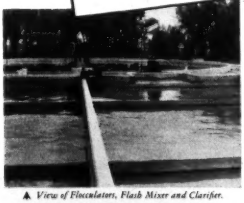
LINK-BELT COMPANY PHILADELPHIA CHICAGO LOS ANGELES 7932-A

LINK-BELT

SCREENS ▲ COLLECTORS ▲ AERATORS ▲ GRIT CHAMBERS ▲ DIFFUSERS

EFFLUENT MUST BE CLEAR

...So Colorado Springs Disposal Plant Uses GENERAL CHEMICAL 'ALUM'



▲ *View of Flocculators, Flash Mixer and Clarifier.*

▲ *Note That Rocks Are Visible Showing Clarity of Effluent.*

Clear, pure effluent is required at the Colorado Sewage Disposal Plant* because the effluent flows into a nearby river, the water of which is used during the summer months by farmers for crop irrigation. *For this reason, it is absolutely essential that the effluent be as clean as possible.*

Clarity and purity of effluent at Colorado Springs are accomplished by chemical precipitation using General Chemical Aluminum Sulfate and a small amount of lime for control of pH. Chlorine is used to reduce bacterial load.

General Chemical Aluminum Sulfate is used because:

1. It is simple to apply, clean and easy to handle.
2. Requires only simple, low cost equipment for application.
3. It is a year round coagulant.
4. Does not necessarily require other chemicals to complete the reaction and there is no complicated problem of properly proportioning two or more chemicals.
5. Can produce crystal clear, near zero turbidity effluent.
6. Precipitated sewage sludge digests easily and yields a high gas production.
7. Treated digested sludge dries quickly and without odor.
8. It is preferred and specified by a majority of important American municipalities.

General Chemical Company will be pleased to extend the cooperation of its specialists to Consulting Engineers who are designing sewage disposal plants and to those desiring better results from existing plants. Your inquiries are cordially solicited. Write to

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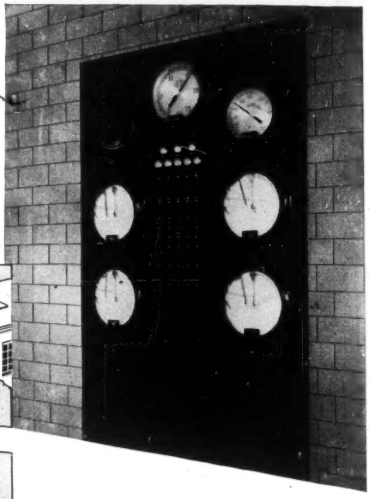
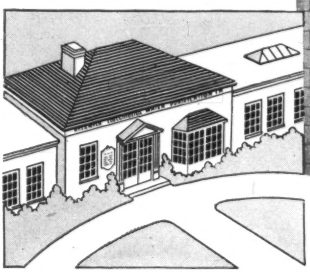
*Designed by Burton Lowther, Consulting Engineer, Denver.

Make the
CONTROL ROOM
"the
BRAIN CENTER"





. . . WITH FOXBORO CENTRALIZED CONTROL

A complete and intelligent supervision of the entire plant at one centralized station—that is what Foxboro Centralized Control makes possible for filtration, water treatment and sewage disposal plants. It indicates levels of all reservoirs and shows what equipment is being used and what is idle. It enables the operator to exercise complete and dependable control over all valves, pumps and other equipment throughout the plant.

Foxboro Centralized Control is characteristic of modern water treatment engineering. Appropriate instruments, carefully selected, conveniently grouped, not only improve plant efficiency, but lower operating costs. Foxboro engineers will gladly assist architects, engineers, and superintendents on any phase of plant instrumentation. Write for full information and our new Water Works Bulletin No. 233. If requested, we will also send Bulletin 232, "Instrumentation of Modern Sewage Disposal Methods." **The Foxboro Company, 162 Neponset Avenue, Foxboro, Mass., U.S.A.** Branch offices in 25 Principal Cities.

FOXBORO
REG. U. S. PAT. OFF.
RECORDING · CONTROLLING · INDICATING
Instruments
TEMPERATURE · LIQUID LEVEL
PRESSURE · FLOW · HUMIDITY

HERE'S HOW NORTH TARRYTOWN, N.Y., CUT THEIR SEWER-LINE COSTS

LIGHT IN WEIGHT, Transite is easily handled at North Tarrytown. Its 13-foot lengths reduce the number of joints required. Villard Construction Co., contractors, found that these features made laying to exact grades easier . . . that they helped speed up work and reduce costs.

FLATTER GRADES are possible on this North Tarrytown sewer line, because Transite has an unusually smooth interior surface. Sewage flows freely at all times. And Transite joints are exceptionally tight . . . keep infiltration to a minimum.

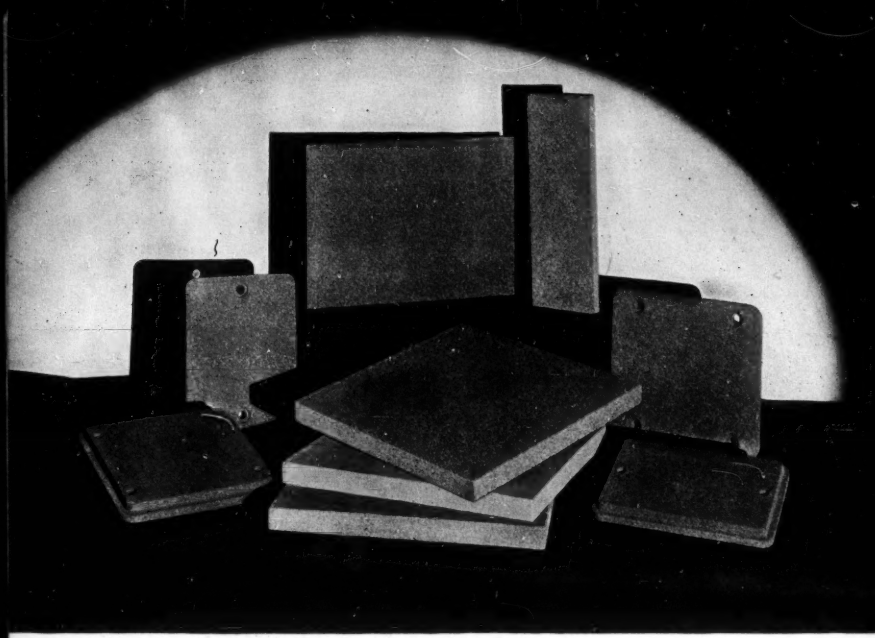
Shallower trenches, flatter grades and fewer joints feature recent installation of J-M Transite Sewer Pipe

UNUSUALLY severe conditions at North Tarrytown made selection of sewer pipe a difficult problem. Because the line runs through a filled salt marsh, soil is highly corrosive and there is danger of a large amount of infiltration. Ground is low, requiring exceptionally flat grades. And speed of construction was important.

To meet all these requirements, engineers Lawlor, Baulsir and Raisch selected 4,500 feet of 14″ and 20″ Transite Pipe for the intercepting sewer. Made of asbestos and cement, this durable material offers high resistance to corrosion. It is supplied in long, light lengths that speed up work and reduce the number of joints in the line. Joints stay tight and, in many cases, because of Transite's unusually high carrying capacity, grades can be flatter, trenches shallower or smaller pipe used.

Before you plan your next sewer line, check up on J-M Transite Pipe. Write for brochure TR-21A. And if you are interested in Transite Pipe for water lines, send for brochure TR-11A. Johns-Manville, 22 E. 40th St., New York, N. Y.

JM Johns-Manville
TRANSITE PIPE
The MODERN MATERIAL for Sewer and Water Lines



A Size and Shape of Plate

to Meet the Need of Every Activated Sludge Plant

EFFICIENCY of diffuser operation—long life with lowest pressure loss—involves a knowledge of application and manufacture that only experience can supply. Plates of widely varying characteristics can be supplied to the same permeability rating.

Norton experience is founded on fourteen years of manufacture of diffuser mediums for sewage plants backed by over fifty years' experience in the manufacture of ceramic products. Norton Porous Plates and Tubes "fit" the job and give the best "all around" results.

These porous mediums are made in Norton plants in Canada and England as well as the United States.

NORTON COMPANY, WORCESTER, MASS.

New York Chicago Cleveland

Norton Company of Canada, Ltd., Hamilton, Ontario

Norton Grinding Wheel Co., Ltd., Welwyn Garden City, England

NORTON POROUS MEDIUM

BARBERTON, OHIO

24" OD sewage line constructed during 1937 from southeast Barberton to disposal plant. Dresser Steel Couplings, Style 38, used exclusively —to provide flexibility and simplify installation. *Pipe:* plain-end, steel. *Contractor:* Gallagher & O'Horo (Youngstown). *Consulting Engineer:* Barstow & LeFeber, Inc. (Akron).

See what "DRESSERS" *offer* before you build that next sewage line!

Looking for pressure-tightness, non-infiltration, ease and speed of installation, absorption of expansion, no unforeseen expenses—in your pipe joints? ALL of these advantages will be yours, if you use Dresser Couplings on that next raw-sewage, sludge, outfall, air, or water-supply line. There's a wealth of information on modern pipe-line construction in our general catalog No. 36. Yours for the asking!

Dresser Catalog No. 36

DRESSER PIPE COUPLINGS

Cross section of Dresser Steel Coupling, Style 38, showing how it joins plain-end pipe in a flexible, tight connection. Sizes: ¼" ID to largest pipe made. (A complete line of cast, insulating, reducing, and long couplings, also ells, tees, etc., available.)

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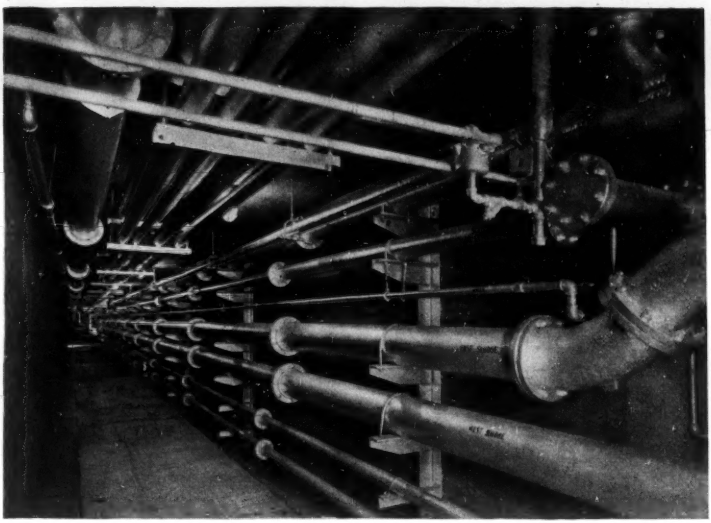

Cast iron pipe installed in Filtration and Incineration Building at sewage treatment plant for Minneapolis —St. Paul Sanitary District

SOUND planning for a treatment plant—even though it be 100 per cent cast iron pipe equipped—can go awry unless the influent mains are also cast iron. For cast iron mains have joints that are tight, *permanently* tight, and infiltration-proof. The material itself—cast iron—is impermeable. The line will always be free from tree roots and ground water; immune to acid trade wastes. Its life will be more than a century.

CAST Q IRON

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Sewage Research:

Research in Sewage Chemistry, Sewage and Waste Treatment and Stream Pollution. A Critical Review of the Literature of 1939. By W. Rudolfs, *Chairman*, F. R. Camp, G. P. Edwards, H. A. Faber, A. J. Fischer, H. W. Gehm, A. E. Griffin, H. Heukelekian, R. W. Kehr, E. W. Moore, Wm. E. Stanley, L. R. Setter, L. W. Van Kleeck and S. I. Zack 189

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Sewage Research

RESEARCH IN SEWAGE CHEMISTRY, SEWAGE AND WASTE TREATMENT AND STREAM POLLUTION

A CRITICAL REVIEW OF THE LITERATURE OF 1939

By W. Rudolfs, *Chairman*, F. R. Camp, G. P. Edwards, H. A. Faber, A. J. Fischer, H. W. Gehm, A. E. Griffin, H. Heukelekian, R. W. Kehr, E. W. Moore, Wm. E. Stanley, L. R. Setter, L. W. VanKleeck and S. I. Zack

Demand for cleaner streams, less health hazards and better living conditions are the stimulants for invention of new and improved methods of sewage and waste treatment. Invention is a gradual process accomplished by many investigators, studies, trials and development. Progress in one year may appear to be slow, or very rapid in another. In many instances the research work conducted seems to be remote from the daily operation of a plant or appears to have no direct bearing on the design of new structures or equipment. Properly conducted research should result in a better understanding of existing processes, lay a foundation for improved procedures, stimulate development of new methods and show the need for advances in equipment.

The extraordinary rapid growth in sewage treatment together with the progress in waste treatment requires more and more research and extended plant experimentation. During the year a great number of papers embodying the results of such research and experimentation have been published. Studies on fundamental principles have been continued and more work of general interest in stream pollution has appeared. Special attention should be paid to the section dealing with trade waste treatment. Most of the work is still along lines adopted from water and sewage experimentation, but there is a very definite tendency—growing year by year—of fundamental work to develop processes specifically fitted for treatment of specific wastes and recovery of by-products. General interest in by-product recovery from sewage and waste is much greater than some years ago. The possibilities are being explored, no doubt influenced by economic and war conditions, of salvaging valuable products which previously were destroyed or discharged. Perfection of processes in use, refinement and greater care of operation, often resulting in lower costs, has continued. The annual review is presented as evidence of progress. The review is not complete in the sense that all papers published were considered, but sufficient to indicate work accomplished, trends and possibilities as shown by the results obtained. In this respect the commit-

tee becomes more and more critical and attempts to evaluate the work when it seems of help to the reader.

Chemistry and Biology

The amount, nature and behavior of colloids in sewage are significant for coagulation, bioflocculation and biological oxidation processes. In a review by Rudolfs and Gehm (202) on the occurrence and rôle of colloids in sewage and sewage treatment it is stated that the amount of true colloidal sols in sewage is probably less than 10 per cent of the total suspended solids. This figure is similar to that reported earlier by Mills. In fresh solids the amount of colloids is relatively low, they increase during digestion and then decrease as digestion nears completion.

Samuel (205) divides flocculation of negative colloids by a negative ion into two stages: (1) preferential adsorption of hydroxyl ions on colloidal surfaces, increasing the negative charge, and (2) the metallic ion produces flocculation probably by neutralization of the charge. The hydroxides of Ba, Ca and K were far better as flocculating agents for finely divided coal and clay suspensions than the sulfate, nitrate or chloride. Brewery and paper pulp wastes were not sensitive to hydroxide adsorption but were to sulfate and chloride.

In continuation of the studies of the effect of gas bubbles on the coagulation of organic matter in sewage, Williams (258) endeavored to rule out the possibility of the formation of new surfaces by the deposition of carbonates. Experiments were accordingly conducted with O_2, H_2 and N_2 both alone and in conjunction with 1.0 per cent of CO_2. The results obtained indicate that the coagulation of dispersed material present in sewage by the different gases was not affected by the presence of CO_2 and therefore the formation of new surfaces by the deposition of carbonates was not a factor in the coagulation of the dispersed matter by bubbles of gas. Bubbles of gas passed through sewage sterilized by ultra violet light and unsterilized sewage gave only a small difference in the amount of organic matter flocculated. It was concluded that coagulating action was mainly physical though biological action may play some part.

Microorganisms capable of attacking a great variety of compounds have been recognized. Compounds such as phenol, arsenic, paraffin, hydrogen, methane, carbon monoxide and hydrogen sulfide, etc., have been known to serve as sources of food and energy for bacteria. Therefore, it is not surprising that Jones and Scott (121) found bacteria in the soil, water and sludge of mine fire areas and electrical conduit manholes capable of oxidizing both carbon monoxide and hydrogen. Although no isolation of the organisms was attempted it is stated that only one type of bacterium was observed.. The ability to oxidize was reduced when the culture was stored in the absence of these gases. This was attributed to the predatory activities of rotifers, nematodes, and protozoa in the culture. In anaerobic locations such as sewers,

manholes and in sludge banks where these gases may be produced, the oxidation that occurs when these gases come in contact with air, such as in the atmosphere of the sewers, becomes a distinct possibility. This action would be analogous to the production and oxidation of hydrogen sulfide under similar circumstances.

Although odors around sewage plants are primarily traced to hydrogen sulfide produced from the reduction of sulfates there is little knowledge as to the organisms responsible for this process. Extensive morphological studies conducted by Starkey (233) showed that probably most of the organisms described as producing hydrogen sulfide from sulfates can be classified under one species—*Vibrio desulfuricans*. This organism when grown at 30° C. is a small non-sporulating vibrio, or short or long spirals, but when grown at 55° C. it is transformed to a spore-bearing type and a larger vibrio shape. Here, for the first time a profound change in the morphology of a given organism has been induced by temperature. With the information available as to the identity and growth characteristics of the organism it becomes possible to investigate the occurrence and abundance of hydrogen sulfide producing organisms in sewage and the effectiveness of preventive and control measures on their numbers and activities.

During recent years considerable information has become available regarding the physiological effects of various substances in promoting plant growth promoting substances. Therefore, the search of these substances on wastes and their agricultural utilization has assumed importance. Rudolfs and Heinemann (203), continuing the search on growth promoting substances in sewages and sludge, reported that such substances are present in fresh solids, septic solids and activated sludge. The quantity of various growth-promoting substances was less in activated sludge than in raw solids. Digestion, heat drying and drastic chemical treatment reduced the quantities of these substances. Rehling and Truog (186) could not detect the presence of plant hormones in Milorganite, but when this product was incorporated in sand or soil appreciable quantities of heteroauxins (indole substituted fatty acid type) were produced as a result of bacterial decomposition. They further showed that Milorganite contained such elements as copper, zinc, lead, nickel, cobalt, titanium, barium, manganese, aluminum, etc., in small quantities but which might be important for plant growth. Thus in addition to the main fertilizer ingredients such as nitrogen and phosphorous Milorganite might contribute these elements as well as some plant hormones when used as a fertilizer.

The presence in soils of a great many bacteria, molds and actinomyces capable of producing auxins when grown in cultural media is reported by Roberts and Roberts (192).

The effect of dissolved oxygen tension on the rate of oxygen uptake has an important bearing on the B.O.D. determination as well as the sewage oxidation processes such as the activated sludge process and trickling filters. Conflicting views have been held on this subject. Additional evidence has been reported by Zobell and Stadler (267)

indicating that within a range of 0.66 to 7.99 p.p.m. of dissolved oxygen, the uptake of oxygen by lake water was not influenced by the initial dissolved oxygen concentration. Additional studies with certain pure cultures of lake bacteria showed that respiration was not a function of oxygen tension.

In contrast to Sir Alexander Houston's earlier findings in regard to the prolonged viability of cultivated typhoid bacilli in water in comparison with uncultivated forms Kabler, Pierce and Michaelson (122) report that the resistance of *E. typhosa* to the killing action of chloramines is materially reduced by prolonged residence in artificial media. It is further stated that strains of *E. typhosa* isolated at approximately the same time may exhibit considerable differences in resistance to the action of chloramine. This evidence points to a possible danger in the use of old laboratory strains in the determination of the effectiveness of chloramine as a disinfectant.

The rôle of bacteriophages in reducing pathogenic bacteria in surface waters has been long a matter of conflicting evidence. From tests conducted by Dinger, Marseille and Tesch (45) it appears that bacteriophage activity is not very important in the destruction of typhoid bacilli in surface waters. The rapid reduction of these bacteria in natural water courses is considered to be due to the biological action of other bacteria and protozoa.

Biological surveys of streams and lakes receiving acid mine waste, made by Lackey (138), revealed a variety of microscopic forms. At or below pH 3.9 the number of species found in any given habitat was very small. After the strip pit lakes have been sealed to reduce acid waste there is little chance for them to become productive except by the initial development of chorophyll-bearing organisms.

Several theories have been advanced as to the cause of trickling filter unloading. Although the activity of worms as a possible factor in unloading has been mentioned, no definite evidence has been advanced. Reynoldson (189) has filled this gap in his report on the life habit and rôle of the Enchytraeid worm *Lumbricillus linaetus*. It is stated that this worm feeds primarily on the alga *Phormidium* which grows on the surface of the bed. In the spring when this alga becomes abundant on the surface the *Lumbricillus* migrates and feeds on the alga, changing the film from a leathery to a spongy condition and causing unloading. With the unloading the worms are driven deeply into the bed and a large portion of them pass out in the effluent. The alga rapidly reforms on the surface and the worms migrate into it again when it is sufficiently thick. The absence of unloading in summer when the growth is again spongy is attributed to the higher rate of regeneration of the alga owing to increased temperature and sunlight. In the winter the worms are driven down to the depths of the bed. The experimental introduction of these worms into filter beds in which the solids were accumulating rapidly cleared the medium, but if the bed is very badly choked and septic, the worms may not be able to carry out this function.

O'Shaughnessy and Roberts (172) advance the view that Adeney's two-stage oxidation does not apply under certain conditions. When some of the humus material produced during the nitrification stage is introduced, carbon and nitrogen oxidations proceed simultaneously and the oxidation of ammonia does not depend on the absence of unoxidized carbon but upon the presence of humus solids. The function of these humus solids for the nitrification is not explained but it can be readily ascribed to the introduction of nitrifying bacteria. In other words, the failure of the oxidation of ammonia simultaneously with the oxidation of carbonaceous materials is not due to inhibition of nitrification by carbonaceous material but to the slower rate of development of nitrifying bacteria.

Williams (259) in a critical discussion of the biozeolitic theory of clarification stage of activated sludge favors adsorption as the probable mechanism of the removal of organic materials by activated sludge. A full explanation must include both base and acid exchange mechanisms as indicated by Setter, Ridenour and Henderson but no evidence has been produced to show the passage of ions from the sludge to sewage.

Aeration with M-phenylenediamine (acid exchange resin) for 15 minutes resulted in the clarification of sewage according to the Report of the Water Pollution Research Board (253). With sulfited quebracho tannin resin (base exchange properties) no clarification of sewage was obtained.

Dickinson (42, 43, 44) tried unsuccessfully to determine the oxidation-reduction potential of activated sludge colorimetrically by means of methylene blue. Subsequent work with other dyes showed that dyes containing electropositive ions were adsorbed by the sludge, indicating that the sludge particles were negatively charged.

Ingols (113) in a study of the hydrolytic enzymes of activated sludge showed a marked increase in pepsin during the development of activated sludge from sewage but only a slight increase of lipase, diastase and trypsin. Lipase, pepsin and diastase were found only on the surface of the sludge while trypsin was found also in the liquor. During the purification period the enzyme activities in the mixture of activated sludge and sewage showed only a small change. With longer periods of aeration, however, marked changes in enzyme activity were shown. Diastatic activity of activated sludge was increased 500 per cent by adding starch to the sludge. When the products of hydrolysis accumulate, due to the lower rate of assimilation of these products by the organisms, the rate of hydrolysis is adversely effected. It is concluded that clarification of sewage is correlated with biophysical properties of activated sludge while purification is correlated with biochemical property and enzyme activity.

The use of CO_2 production as an index to biochemical oxidation process of activated sludge was criticized by Wilson and McLachlan last year on the basis that only 10 per cent of the transformation products of carbon originally in sewage appears as carbon dioxide in the

effluent air and that the transference of carbon from sewage to the sludge is the major purifying effect. More recently results have been obtained by Heukelekian and Littman (98) which show that as much as 65 to 75 per cent of the organic carbon of sewage removed by activated sludge during the purification was recovered as CO_2. The discrepancy between these two contradictory views is explained on the basis that Wilson and McLachlan calculated the percentages of CO_2 released on the total carbon input of both settled sewage and activated sludge rather than on organic carbon lost from sewage upon aeration. Jenkins and Roberts (117) have also obtained a value of 61.4 per cent of the carbon removed from liquor oxidized to CO_2.

Experiments given in the Report of the Water Pollution Research Board (253) on the effect of temperature on the purification of both milk washings and sewage by the activated sludge process indicate that the optimum temperature is between 20 and 30° C. Milk washings aerated at 2° C. with activated sludge gave a sludge that settled slowly and an effluent with a high B.O.D. (200 p.p.m.). The B.O.D. of the effluent obtained at this temperature after filtration through paper was only 20 p.p.m. indicating that most of the oxygen consuming materials were in suspension. At 45° C. the effluent had a high B.O.D. both after settling and filtration through paper, indicating that a large proportion of the oxygen consuming materials were in solution. The percentage of fat in activated sludge was least when the mixtures were aerated at 30 to 35° C. and highest at 2° C.

Biological work indicated that with the addition of whey washings, although the concentration of *Sphaerotilus* was decreased, bulking was more pronounced than with milk washings. Observations showed that when whey washings were treated, bacteria did not form zooglea as with milk washings.

Additional work on the effect of temperature on the activated sludge process is reported by Kenichi Chuda (125). In a series of laboratory experiments with weak sewage fortified with egg albumen, the transformation of nitrogen was studied at different temperatures. Very little change in the ammonia, organic nitrogen and B.O.D. of liquor was obtained even after 10 hours of aeration at 3 to 7° C. When the temperature was raised to 12 to 17° C. purification as measured by the above yardsticks was considerably improved. Temperatures of 22 to 27° C. were the optimum for biological purification and B.O.D. removals, although ammonia removal and nitrate formation were faster at 30 to 36° C. Most rapid sludge build-up took place at 20 to 30° C. The same author (126) reported in detail the transformations of nitrogen taking place in the aeration of sewage with activated sludge at a given temperature. The forms of nitrogen studied were ammonia, organic, albuminoid amino, nitrite and nitrate nitrogen.

Respiratory quotients for the different activated sludges tested by Sawyer and Nichols (209) varied from 0.59 to 0.94. Neither the suspended solids concentration nor the temperature showed a definite effect on the R.Q. values. The source of sewage and the character of

activated sludge had an influence on the R.Q. values. The effect of the addition of pure substances such as glucose, peptone or soap to activated sludge and the effect of storage of sludge and sewage without aeration were also determined. Further information on the respiration quotient of sewage is reported by Masaru Hiura (150). Oxygen consumption was determined by the Fransenmeier-Sierp method. Carbon dioxide production was determined either in conjunction with the oxygen in the Fransenmeier-Sierp method or separately. When carbon dioxide and oxygen were determined separately, higher R.Q. values were obtained, probably due to the fact that by this method air was bubbled through sewage to determine carbon dioxide production, resulting in higher values. Forty-four samples of sewage from Kioto were thus tested and the R.Q. values varied from 0.67 to 2.10 with an average of 1.03. The result of purification of sewage was to decrease the R.Q. values. The R.Q. values of sewage with additions of pure substances such as glucose, peptone and olive oil were also studied.

The influence of temperature on the digestion of activated sludge without seed was studied by Ishimatsu Mitsuo (115). The criterion used was the transformation of nitrogen during a period of seven days. It was found that the rate of transformation of all types of nitrogen (total, organic, albuminoid, ammonia, amino, nitrite and nitrate) was lowest at 0 to 5° C. and highest at 55° C. The observed increases in nitrates can be disregarded as they are calculated on the basis of values on the fourth decimal place.

Those who are interested in the technical aspects of anaerobic fermentation and methane production will welcome the compilation of all the work published on this subject during the past ten years at the University of Illinois by Buswell, edited by Hatfield (31). Some unpublished material is also included.

Methods

The importance and general significance of laboratory tests for the study and control of sewage treatment processes was recently summarized by Hatfield (89). Minimum tests for these are grouped according to treatment process. Suspended solids and biochemical oxygen demand are given as the most valuable plant performance and control tests. It is not surprising, therefore, that studies of these determinations, or substitutes for them, appear in the past year.

The photronreflectometer was applied to the measurement of turbidity in sewage with success by Gehm and Trubnick (66). This device employs the measurement of the current from a photronic cell set up by light reflected from suspended particles. Readings are made on a microammeter. This apparatus gives greater accuracy, requires a very small sample, eliminates the personal factor and can be applied to a wide range of turbidites.

Outstanding are the studies on the improvement and simplification of the dissolved oxygen test for effluents, streams, and the B.O.D. de-

termination. Investigations by Barnett and Hurwitz of the Sanitary District of Chicago (17) indicate that the Alsterberg azide modification of the Winkler method eliminates nitrite interference. Since the sodium azide is contained in the alkaline-iodide reagent, the procedure is identical with the Winkler method. This simplification of procedure yields results substantially equivalent to the more involved Ruchhoft *et al* Alsterberg modification (194) and more reliable than either the straight Winkler or the Rideal-Stewart modification on nitrifying liquids. The azide is known to be quite unstable, yet the alkaline-iodide-azide reagent has been found stable for over three weeks, presumably, if stored in brown bottles.

The Winkler method for the determination of D. O. was found inaccurate by Sibata (217). He found the Miller method for determining D. O. more satisfactory. This method consists of the oxidation of an alkaline solution of ferrous hydroxide tartrate, the end point being indicated by the reduction of methylene blue. The D. O. in the B.O.D. tests were determined by this method and it is stated that sodium nitrate does not interfere.

The dilution water for determining the B.O.D. of some industrial wastes requires nitrogen and phosphate enrichment according to Nichols (170). As little as 2.5 p.p.m. ammonium sulphate and 0.1 p.p.m. KH_2PO_4 added to $NaHCO_3$ (300 p.p.m.) dilution water increased the 5-day B.O.D. of paper mill wastes by a maximum of 685 per cent.

Comparison of the Sierp and dilution method for the determination of B.O.D. made by Kenichi Chuda (126), indicated that the dilution method gave higher values with greater dilutions and therefore the Sierp method was considered preferable. However, such results are always obtained with the dilution method when the dilution water is unsatisfactory.

Recent investigation by Levine *et al* (140) on the optimum temperature for maximum growth and count of pollutional organisms indicates the interesting possibility of standardizing an incubation temperature between 25 and 30° C. for the usual biochemical and bacteriological tests. Such suggestions may cause criticism, but a uniform incubation temperature below 37° C. and above 20° C. has merit from the standpoint of equipment and operating cost. The conditioning of a small room at $\pm 30°$ C. is within the economical possibilities of even small American sewage treatment plants.

The practical difficulties of obtaining representative samples of raw sewage and sludge is indicated in a report on "Solids Balancing," by Flower, Budd, and Hauck (63) wherein wide discrepancies in computing solids balance were found. On the basis of this report one would conclude that for practical purposes a rapid estimation of sludge solids by the centrifuge method (*S. W. J.*, **7**, 23, 1935) would be satisfactory for sludge conditioning, tank loading, etc. The suspended solids of sewage influents can be made more accurate by determining the settleable solids in a liter sample and the non-settleable suspended solids on a lesser volume of sample by the Gooch method.

Funck (65) reports a simple method for determining ammonia nitrogen. The estimation is based on the titration of HCl quantitatively liberated by the inter-action of NH_4Cl and formaldehyde. The method may serve as a rapid estimation of ammonia nitrogen in sludges or of organic nitrogen after wet combustion.

A modified method for determining ammonia nitrogen is recommended by Sibata (216). Distillation is conducted without the use of any buffers except magnesia when the pH of the sample is below 7.5. The distillation is made into saturated boric acid and titrated back with standard sulfuric acid using methyl orange as indicator. This departure from normal titration with phenolphthalein is made to overcome the error caused by CO_2.

Research in the development of methods for measuring the "activity" of activated sludge continues. The more promising indices are oxygen uptake and carbon dioxide production over short incubation periods. The closed aeration system reported by Butterfield *et al* (32) has been modified in the Indianapolis "Biometer" by Bloodgood (23), and the "Oxygen Utilometer" (Oum) by Sawyer of the Wisconsin State Laboratory Hygiene (206, 207, 208, 209). The latter two units measure the decrease in the volume of CO_2-free air in closed systems as a measure of the oxygen demand of activated sludge mixtures. Considering the rapidity with which the rate of oxygen utilization changes, it appears that the short time B.O.D. values by the dilution method are not so informative as the recording meters. Although satisfactory for research purpose, simplification of design and operating technic, and greater dependability are desirable to adapt present oxygen demand meters to routine control tests.

Chemical Treatment

Chemical treatment continued its rapid advance through 1939. This year was marked by the opening of two large new plants designed for occasional use of chemicals. The St. Paul-Minneapolis installation will treat 134 m.g.d. and the Clayton plant at Atlanta treating 42 m.g.d. (33). The design of new plants at Spindale, N. C., and Albermarle, N. C., are described by Pollock (175) and Moore (163), respectively. The Spindale plant will treat a sewage flow containing 85 per cent industrial waste from rayon and cotton mills. A rapid sand filter will be used to polish the effluent. At Albermarle chemical treatment following trickling filters is featured. An interesting innovation planned here is the addition of the final chlorine to the flash mixing chamber of the chemical treatment unit, in order to take advantage of the rapid dispersion of the chemical through the sewage.

Operation and operating results commanded much attention in the literature. Sufficient time has passed for operators to accumulate reliable data on the newer installations to allow definite conclusions to be drawn as to what can be expected from chemical treatment when operating difficulties have been ironed out and a definite scheme of control put into effect.

Haseltine (87) reports on two years' operation at Butler, Pa. He found that the use of iron salts alone, while giving satisfactory B.O.D. reductions, left a yellow color in the effluent probably due to dissolved or dispersed iron. This effect could be prevented by addition of lime. Excessive coagulant dosages gave poor results. The addition of chlorine to the raw sewage was a necessary adjunct to coagulation. It was not necessary, however, to cary a residual through the plant. The B.O.D. and suspended solids removals averaged 60 and 85 per cent respectively. The same author (88) describes trials, using alum and chlorinated copperas in combination, which accomplished removals of B.O.D. of 72 per cent and suspended solids 87 per cent. Better results at lower cost were obtained with this combination of chemicals than with either coagulant alone. However, the improvement in results did not warrant the added attention necessary to control the feeding of two chemicals. The installing of flexible chemical feed devices of adequate capacity so that any of the common chemicals may be used, to take advantage of price fluctuations, is recommended. The cost of chemicals at this plant averaged about $7.00 per million gallons.

The accomplishments of the plant at Waukegan, Ill., were presented by Swope (237). Here Imhoff tanks are used for settling. Ferric chloride alone produced a B.O.D. reduction of 69 per cent and suspended solids removal of 74 per cent. Lime in combination with this coagulant yielded reductions of 61 and 81 per cent, respectively. The decreased suspended solids removal accompanied by higher B.O.D. reduction, when ferric chloride alone was employed, may be due to hydrolyzed iron present in the effluent, raising the suspended solids results, or reduction of some of the dissolved B.O.D. by reaction with the iron salt which was applied in greater amounts when no lime was used. This observation is not uncommon and perhaps volatile suspended solids of the effluent might be a better index of clarification when such processes are used. The Baylis silicate-alum method was tried at this plant for three periods of several days' duration. A B.O.D. reduction of 63 per cent and a removal of suspended solids of 77 per cent was achieved at a lower cost than other methods of treatment. These results could be produced at a chemical cost of about $4.00 per million gallons.

Improvement in the results obtained with the Guggenheim process at New Britain, Conn., were discussed by Szymanski (239). Here a flow of 9.5 m.g.d. was treated for four months with 37 lb. iron and 18.6 lb. chlorine per m.g. in the form of chlorinated copperas. Using 0.144 cu. ft. of air per gallon and returning sufficient sludge to maintain 1,100 p.p.m. suspended solids in the aeration tanks, reductions of 91 per cent in B.O.D. and 93 per cent in suspended solids were realized. Total cost was $22.11 per m.g. An improvement over the previous year was shown in both cost and removals.

The sewage of the city of Halle, Germany, was treated with varying dosages of ferric chloride by Müller (166). He obtained B.O.D. reductions of from 60 to 65 per cent with corresponding reductions of 87

per cent in suspended solids. Maintaining that the soluble matter comes through the process comparatively unchanged, he found that the increase in gas from the digestors was in proportion to the additional solids removed from the sewage by the chemical. Cost of such treatment was estimated at about $0.08 per capita per year for chemical.

Mom and Schaeffer (159), apparently following experimentation by Jan Smit, treated sewage from a city in Java in an Emscher tank with chlorine, ferric sulfate and lime, and obtained a B.O.D. reduction of 75 per cent. The use of lime in solution rather than suspension led to better settling and improved clarification. This proved a difficult practice as a volume of water one-tenth of the sewage flow was required to apply the lime in the dissolved state. Lime in some form was necessary to produce maximum results.

Data on B.O.D. removals by the Liberty, N. Y., plant were reported (3). Here alum is used exclusively for coagulation. The average B.O.D. removals for three summers were 82, 75 and 69 per cent, respectively. When treating a sewage varying from 300 to 600 p.p.m. B.O.D., an effluent of less than 100 p.p.m. was consistently produced. Higher effluent B.O.D. resulted when large quantities of laundry waste were present in the sewage. The volume of sludge seems to be increased.

In discussing some of the newer developments in Holland, Rudolfs and Kessener (204) relate the method of treatment at Tilburg, where the sewage is treated with about 35 p.p.m. of alum along with an alum liquor made by treating the sludge obtained with 400 grams of 60° Bé sulfuric acid per 1,000 gallons. The acidified sludge is allowed to stand three days. At the end of this time the sludge has compacted, leaving a clear supernatant which has coagulating properties. About 80 per cent of the alum is recovered by this process and the B.O.D. of the sewage is reduced 70 per cent.

In Japan, Sibata (216) reports laboratory trials which led him to the conclusion that the iso-electric point of the dispersed matter in sewage is at pH 6.8, because at this value he was able to coagulate sewage with ferric sulfate.

Investigations of the theory of chemical coagulation and the development of better methods of controlling the process have continued. As the chemical demand of sewage varies it would be advantageous to have a method of determining rapidly the coagulant requirement. The jar test method now used is too slow and the sewage has generally been treated by the time results of this test can be obtained. Eldridge (55) attempted to employ cataphoresis measurements for the purpose of predicting the coagulant dosage. His experiments showed that no relationship existed between the point of optimum coagulation, the iso-electric point and the z-potential. If a relationship had existed the method would have been applicable. The optimum point for coagulation, judging from visual observations, occurs at the maximum z potential, which point is not well defined. Some interesting conclusions, however, could be drawn from the data obtained. The author

believes that coagulants serve a dual purpose in clarification. First, a floc is formed by the reaction between the alkalinity in the sewage and the coagulant. This floc maintains a charge which is opposite to that of the dispersed matter. Thus, the second action, that of attracting the dispersed particles, takes place. He believes that the nature and amount of colloidal matter determines the dosage of coagulant necessary. The above explanation appears to be essentially correct and is supported by the data presented, but the explanation is not complete, since all the observations made in the application of chemical treatment are not answered. However, more of the facts fit this theory than others, many of which are rather close to speculation.

Working with hydrosols of iron prepared by boiling and dialyzing ferric chloride solutions Elder and Stahl (53) found these preparations to be less efficient coagulants than ferric chloride for sewage and dairy waste. They concluded that this was due to the fact that the sols were of larger particle size than was the solution of the salt. As the sol produced by boiling had chlorine ions present and the dialyzed sol did not preclude them, this ion may be responsible for the stronger action of the salt. When the sols age the particles become larger and their coagulating power decreases. The authors claim that the initial particle size of the coagulant alone controls the effectiveness of the coagulant according to Von Weimarn's theory. Further evidence for this contention is held to be the difference in type of floc formed by the sols and the salt. Sol flocs were granular as compared to the gelatinous floc formed by the ferric chloride. They explain the difference in action as one of crystal lattice formation. The salt forms a lattice which can absorb most of the suspended particles while the sol lattices have a lower capacity for holding them. Those which will not fit in the sol lattice remain dispersed in the liquor. It appears that the basic observations are corect as far as they go. For pure sols this conception holds quite well but the character of the sol and the dispersing liquor are highly variable in sewage and the curves presented cannot be classed as general.

In investigating the cause of the coagulant demand of sewage, Gehm (67) concluded that organic matter, in solution or extremely fine suspension (having no Tyndall cone effect), was responsible for the demand. Once the demand of this material was satisfied, very small quantities of ferric chloride were required to coagulate sewage. Thus it is the dispersion medium, rather than the visible dispersed particles, that is responsible for the demand. Ammonia-nitrogen content was found to be an index of coagulant demand although the ammonia itself was not responsible. Urine raises the demand appreciably and the ammonia content is probably an index of the amount of urine present in sewage. There are, therefore, three actions when a coagulant is added to sewage. In addition to the two presented by Eldridge the interfering substances must be satisfied before a floc sufficiently active to remove all the dispersed matter is formed. The type of coagulation curve produced will then depend on the amount and type of the inter-

fering materials rather than on the dispersed matter itself. This does not mean that the character of the dispersion does not affect coagulation, but it does appear that once the dispersion medium is properly conditioned the dispersed particles are very readily coagulated.

Interest in flocculation is evidenced by the appearance of three papers on the subject. The essentials for efficient agglomeration are laid down by Velz (247). He says that flocculation should be an independent operation, insuring intimate contact of particles to allow formation of a tough, rapidly settling floc, so that re-dispersion will not take place. Darby (39) states that flocculation produces consistent results regardless of raw feed and that when chemicals are applied substantial savings will be obtained by flocculation. He discussed new units employing combined flocculation and sedimentation.

The search for new and better coagulants and improved apparatus with which to apply chemical treatment has continued as evidenced by the literature and patents granted. A process involving elecerodialysis of sewage to aid in coagulating with chemicals was granted to Slagle (224). Another Slagle patent (225) covers the preparation and use of diferric tetrachloride mono sulfate ($Fe_2Cl_4SO_4$) as a sewage coagulant. Darby, Weber and Fischer (38) patented a device which combines the flocculation and sedimentation processes in a single unit.

Trickling Filters

Trickling filters continue to be popular for oxidation treatment of sewage in the smaller and medium size plants. Inquiries in 1937 (232) and 1938 (13) indicated that there were 947 municipal installations in the United States in 1937 and 1,140 in 1938, compared with 371 installations in 1926, an increase of over 200 per cent in twelve years. Particular attention in research and new development has been directed toward high-rate filtration, re-circulation of the filter effluent and stage filtration.

Conventional Filters.—Pönninger (176) found that the amount of water held by the film was dependent upon the load placed upon the bed and that the amount of film in the filter was dependent upon the type and size of filter material. It is concluded that with sufficient oxygen supply the degree of purification depends upon the amount of biological film, together with the diameter and depth of the bed. In a subsequent article the same author (178) observed that since purification of sewage in a trickling filter is primarily dependent upon the time of contact, and the contact time upon the amount of biological film, which in turn is affected by the size and shape of the filter, construction cost was a dominant factor. A series of curves is presented to show the relative cost of various sizes of open filters, and of closed filters with artificial aeration, and the part played by the size of the filter material. A filter with a diameter of 54 ft. and an effective volume of 5,560 cu. yds. is considered the most economical.

Experiments with an artificially aerated trickling filter gave the opportunity to obtain information on oxygen consumption. As a re-

sult of these studies Pönninger (177) states that oxygen demand depends upon the staleness of the sewage, the amount of air supplied and the volume of sewage treated. The author concludes that oxygen consumption in a filter is only slightly affected by the variations in the strength of sewage. With increased air supply oxygen consumption increases greatly. Only organic substances deposited in the filter were oxidized by increased aeration, thereby reducing sludge formation in the bed. With decreased air supply, increased clogging occured, reducing oxidation and purification. With increased loading the oxygen consumption increased in direct proportion until a limit was reached. Without artificial aeration the load applied must be reduced to obtain equal purification.

In a further communication Pönninger (179) compared the B.O.D. reduction of sewage obtained in a trickling filter with the oxygen consumption of the bed by determining the B.O.D. remaining in the sewage and the oxygen reduction in the air blown into the filter. During the rest periods when no air was applied, oxygen reduction took place but it was considerably increased by the aeration. The increase in oxygen consumption was considered due to the oxidation of the accumulated sludge. The oxygen consumption of the sludge varies. To determine how far the material should be oxidized before discharge into a given water course, the equation proposed is B.O.D./day $= \Sigma$ Q B.O.D./hr., where B.O.D./day is the total oxygen demand per day observed, Q the hourly quantity of sewage and B.O.D./ hr. the average hourly B.O.D. of the sewage.

On the basis of observation and experiments during the ripening of filters Pönninger (180) compared the degree of sludge accumulation with the contact period of the sewage. The accumulated sludge repels water while the film absorbs it so that the contact time during the working-in period is less. The absorption of the water by the film aids in the purification. It is clear therefore that the amount of film and not the surface of the filter media determines the contact time.

In comparing trickling filter efficiencies Pönninger states that (181) water consumption and B.O.D. of sewage give only approximations but are not measurements of efficiency. The only proper measuring stick that can be used is the oxygen consumed during purification. For instance with the same B.O.D. in the effluent one filter has a higher performance than another.

City	Water, liter/day	B.O.D. Influent	B.O.D. Reduction
Small	60	600	520
Medium	100	450	370
Large	300	140	60

Mahlie (147) made an analysis of the loadings of the trickling filters at Fort Worth during a four-year period. When the loadings

were high (on the basis of the B.O.D. applied) due to the packinghouse wastes, nitrification dropped. Sewage pre-treated in four different ways was applied to the filters, namely: (1) Imhoff tank effluents (2) primary tank effluent (3) aerated primary tank effluent and (4) aerated and settled primary tank effluent. The amount of air used during these last two periods was 0.43 cu.ft./gal. during 5.0–5.5 hours. An effluent containing the least amount of suspended solids and B.O.D. was obtained when the sewage was aerated and settled. The largest removal of pounds of B.O.D. was accomplished by the filter which received aerated sewage. During the first two periods there was slight ponding but not during the latter two periods.

There appears to be a greater tendency to accept B.O.D. determinations as the criteria for evaluating filter loadings and performance. However, Imhoff (111) preferred per capita rates of sewage flow per cubic meter of filter using 'population equivalent' values for organic industrial wastes (merely multiplying B.O.D. by a per capita factor).

Knechtges (130) has graphically summarized the relation between B.O.D. load applied and B.O.D. removed for long term operating results of eight conventional rate plants, indicating B.O.D. removals between 70 and 90 per cent for loadings ranging from 100 to 1,650 pounds 5-day B.O.D. per acre ft. per day. Similar data from short term experimental filters indicate B.O.D. removals between 60 and 70 per cent for loadings from 5,000 to 7,000 lb. 5-day B.O.D. per acre ft. per day.

McIntyre has reported (152) two years operating at Cedar Rapids with average B.O.D. loading of 1,342 lb. per acre ft. per day (sewage strength about 350 p.p.m.) and an average of 78 per cent removal, maximum loadings being as high as 2,560 lb. B.O.D. per acre ft. per day for a single day.

The joint Wisconsin and Minnesota tentative standards for high-rate filters (35) specify "That filter loading should not exceed 1.0 pound 5-day B.O.D. per sq. ft. of filter per 24 hours based on an 8-ft. depth (equivalent to 5,445 lb. per acre foot) and maximum dosage not to exceed 26 m.g.a.d. This appears to be a very liberal allowance.

High Rate, Enclosed, Aerated, Heated, Stage and Recirculated Filters.—Piret, Mann, and Halvorson (174) studied the rates of air flow through filters at different rates of application. The flow of air with continuous water distribution after equilibrium was established, was a straight-line function of the difference between the temperature of the air and of the water and was independent of the dosage up to 20 m.g.a.d. Descending water by itself had only a negligible effect on the air flow. The direction of air flow was influenced by difference of water temperature and air temperature. During intermittent dosage, pulsation in air flow took place as a result of the increased heat transfer during the dosing period. For a given amount of water dosed on a filter intermittent dosage did not bring about as much air flow as continuous dosage.

Montgomery (162), in a general discussion of the rates of application, pointed out that the conventional filter operates with a high

fluctuating instantaneous rate and a low daily capacity, while the "aero-filter" operates with a low instantaneous rate but high daily capacity. It was stated that the quantity of nitrates formed was influenced by the quantity of sludge in the filter and that the higher the stability of the sludge (longer sludge is held in the filter) the greater the tendency to pond.

Goldthrope (70) conducted some experiments with high-rate filtration (10 and 20 m.g.a.d.) in concrete pipes 8 ft. long and 2 ft. in diameter. The media was 2 to 4 in. clinker. Using the sodium chloride test it was found that the contact time was 20 to 25 minutes at 10 m.g.a.d. and 7 to 9 minutes at 20 m.g.a.d. General ponding of the surface was not noticed, although local ponding occurred. Flies congregated under the ponded portion protected from the heavy wash. Here they laid their eggs and the larvae cleared up the ponding. Growths on the surface did not interfere with purification. Although ventilation was reduced by the growths this was counterbalanced by longer period of contact. Growths within the bed were small and chanelling was not evident except in the upper foot. With warmer weather flies increased at such a rate that the bed was stripped clean and the larvae, left without a foothold on the medium, were washed out until growth increased and fly population was re-established. Purification as measured by B.O.D. removal was 55 per cent at 10 m.g.a.d. and 45 per cent at 20 m.g.a.d., with a B.O.D. of applied sewage of 160 p.p.m. At the 10 m.g.a.d. rate 8,800 lb. B.O.D. was removed and 14,000 lb. at the 20 m.g.a.d. rate.

Sohler (228) reported that the conventional trickling filters at Stuttgart were changed to high-rate filters. Fourteen days after the change a number of clogged areas appeared on the surface but these disappeared entirely. Some nitrification was obtained at the high rates. The removal of B.O.D. was not appreciably lower at the high rates with sedimentation than at the lower rates without sedimentation (original low-rate filters were not provided with secondary sedimentation tanks). The bacterial counts of the effluent from the high-rate filters were many times higher than those from the low-rate filter.

Hamlin and Wilson (82) in South Africa experimented with enclosed ventilated filters during the summer at a rate of 120 gal. per cu. yd. per day. The results showed that artificial ventilation of an enclosed filter was necessary if an effluent of 100 per cent stability was required. The output of the open filter was higher during the summer. It was concluded that temperature was of far greater influence on operation of the open filter than artificial ventilation on operation of the enclosed filter. Blowing air through the filter did not materially assist in the purification when the filter was dosed at a rate of 200 gal. per cu. yd. per day. In model experiments with filters 3 ft. in diameter and 6 ft. deep a dosage of 715 gal. per cu. yd. per day could be handled during the warm weather. Two experimental pipe filters 6 in. in diameter and 6½ ft. deep were constructed. Through one air was blown, renewing the atmosphere 35 times during 24 hours. At

a rate of 300 gal. per cu. yd. per day the effluent from the naturally ventilated filter deteriorated, but this did not occur with the effluent from the aerated filter. Artificial introduction of carbon dioxide had little effect on purification. It was concluded that the beneficial influence of ventilation was not due to the removal of carbon dioxide. In a subsequent paper Wilson and Hamlin (261) gave the results of experiments which substantiated the earlier findings. In winter the enclosed ventilated filter operated at a higher loading than the open filter, whereas in summer the rates of the two filters were almost equal. When sewage fed to the open filters was heated during the cold months the same rate could be maintained as in the warm months. Accordingly experiments were conducted with model filters to determine the optimum temperature, covering a range from 70 to 120° F. Up to 95° F. benefit was obtained by increasing the temperature, but at 100° F. purification and nitrification seriously diminished and became worse with still higher temperatures.

Additional work with inclosed filters was reported from England by Hurley and Windridge (107). Two enclosed experimental filters were constructed. No. 1 was a 13 ft. filter with the top and bottom foot filled with 1½ to 2 in. stone and the remainder ¾ to 1 in. stone. No. 2 was a 6 ft. filter with 1.0 ft. at top and bottom of 2 to 2½ in. stone, and the middle of 1 to 1½ in. stone, designed to treat sewage at a very high rate. This was followed by a secondary filter similar to No. 1 but operated at a higher rate to give complete treatment in two stages. An impulse type distributor was used. Air was supplied at a rate of 200 cu. ft. per min. to No. 1 filter and 600 cu. ft. per min. to No. 2 filter. Sewage contained industrial wastes in high proportion and had an average B.O.D. of 324 p.p.m. and suspended solids of 122 p.p.m. No. 1 filter could purify 145 to 167 gal. per cu. yd. per day, giving a purification of 95 per cent as measured by B.O.D. Such a strong sewage when applied to an open filter could not be treated at rates higher than 50 gal. per cu. yd. per day. No. 2 filter dosed at a rate of 800 gal. per cu. yd. per day gave a B.O.D. removal of 70 per cent without any sign of ponding. When artificial aeration was stopped the effluents deteriorated appreciably. In a subsequent paper, Hurley and Lovett (108) reported that the dosage on No. 1 filter had been increased to 205 gal. per cu. yd. and on No. 2 to 1,070 gal. per cu. yd. with satisfactory effluents.

On the basis of experiments, Husmann (110) concluded that aerated high-rate trickling filters constitute an efficient method of sewage purification. In spite of the fact that no air was supplied for several days considerable purification was accomplished.

Dahlem (37), in a discussion of construction cost of highly loaded trickling filters, concluded that enclosure and artificial aeration were not necessary but that the proper size of filter material, natural ventilation and good sewage distribution were important. Similar conclusions were reached by Nauta (167) at Amsterdam. Artificial aeration and covering of filters is not considered necessary. Good bottom

aeration and proper distribution are important. Imhoff (112) believes that trickling filters can receive much higher loadings than customary heretofore, without interference with purification. All so called new developments have been known for a long time; artificial aeration is not necessary in beds up to 8 ft. deep. Covering of high-rate filters is still less needed except perhaps for fly control but fly nuisance can be greatly reduced by continuous spray applications. Returning of effluents which has been known and practiced for decades is ordinarily unnecessary. It may be helpful when very strong sewage is applied or when filters are only several feet deep and double filtration is to be avoided. In effect, any ordinary trickling filter can be changed to a high-rate filter by greater application of sewage. The important thing is to design the filters on fundamentally correct principles.

The Chicago experiments on high-rate filtration noted in 1935 (173) have been reported (92) covering an operating period of 2½ years, with dosing rates ranging from 20.0 to 30.0 m.g.a.d. The results indicate that for the relatively weak Chicago sewage (48 to 74 p.p.m. 5-day B.O.D.) these rates and possibly higher could be applied with no evidence of clogging, and with monthly average B.O.D. removals, from raw sewage to plant effluent, of about 15,000 lb. per day per acre of filter. The overall percentage reductions in B.O.D. were lower than for plants including conventional rate filters, ranging from about 75 per cent for application rates of 20.0 m.g.a.d. to about 65 per cent for application rates of 30.0 m.g.a.d. Forced aeration and some recirculation was tried for several weeks.

Halvorson and Smith have reported (81) results for a year of operation at Fall River, Wis., using relatively strong screened sewage with 5-day B.O.D. from 150 to 495 p.p.m., resulting in overall B.O.D. percentage reductions ranging from 87.6 down to 56.6 per cent, the lower reductions being attributed to excessive volumes of industrial wastes. The report states that overall reductions of 75 to 85 per cent were indicated when the sewage flow was reduced to 200,000 gallons daily, corresponding to an application rate of 20 m.g.a.d., and with a B.O.D. of about 400 p.p.m., giving a filter loading of 43,560 lb. per acre per day (assuming 35 per cent removal by screening).

Installations of high-rate filters at Bedford, Ia., Paris, Ill., and Lakeland, Fla., have been constructed with guarantees by equipment manufacturers as to operating results. Satisfactory operating tests have not yet been completed.

Edwards and Adams have reported (51) results of operation of several small high-rate experimental filters at the Lawrence Experiment Station using relatively strong domestic sewage (about 500 p.p.m., B.O.D.) and a comparison with the results of similar low-rate filters. Two filters operating 14 months with rates of application of 17.8 m.g.a.d. gave a reduction in B.O.D. of 67 per cent with recirculation of 20 per cent of the filter effluent, and 59 per cent without recirculation. Other tests on three filters with rates of 20 m.g.a.d. gave overall

removal of B.O.D. ranging from 65 to 74 per cent, as compared with 95 per cent for two filters operated at 1.5 and 4.1 m.g.a.d. rates. The high rate filter B.O.D. loadings averaged 5,200 lb. per acre ft. per day as compared with 390 and 1,070 for the lowrate filters. The authors stated that they were able to obtain high reductions of B.O.D. per acre foot per day at the expense of a good effluent. Some clogging troubles were experienced on all the high-rate filters.

The term "bio-filtration" applied by Jenks (118) to a method of "repeatedly passing sewage at high rates of application through a small volume of rock filter medium" has made several appearances in trickling filter literature. This process has been described by Fischer and Thompson (62) as "the pre-settling or detention of the sewage prior to its application to a trickling filter, and the re-circulation of all or part of the filter effluent back to the detention tank." Dosing rates, including re-circulation as high as 125 m.g.a.d., with more usual rates ranging from 20 to 60 m.g.a.d., are suggested to maintain ventilation and prevent clogging. One, two and three stages of operation have been proposed. Seventeen installations were reported (62), ranging in capacity from 0.07 to 3.0 m.g.a.d., of which eight were installed in 1939 and fourteen are located in California. The results of short tests of operating results at Petaluma with raw sewage strengths in B.O.D. ranging from 521 to 636 p.p.m. indicated B.O.D. removals ranging from 89.0 to 97.6 per cent for two-stage operation. The rate of dosage of raw sewage ranged from 5.0 to 10.6 m.g.a.d. with re-circulation ratios ranging from 2.5 to 5.9 so that actual rates of application ranged from 17.2 to 42.1 m.g.a.d. Similar results were reported for Healdsburg, Cal., and San Mateo, Cal. All three of these plants include rotary distributors and filter beds 3 ft. in depth. Fischer and Thompson also reported the results of single-stage experimental filters dosed with strong sewage (288 to 315 p.p.m., B.O.D.) at 60 m.g.a.d. and a re-circulation ratio of 4.0 with filter depths of 2, 4, and 6 ft., in which the B.O.D. removals ranged from 75.5 per cent for the 2-ft. filter to 83.0 per cent for the 6-foot filter.

The construction of a double-stage trickling filter plant at Houston, Texas (12) for treating brewery wastes has been reported by Bushee, the design being based on the results of a pilot test plant.

Re-circulation as an aid toward greater B.O.D. removals for strong sewages has received continued attention since the 1937 reference (73) to Jenk's experiments. Halvorson reports (80) that the return of large quantities of effluent tends to counteract the increase in acidity which develops in the treatment of certain industrial wastes. Thus, at Dayton, Wash., Fox Lake, Wis., and elsewhere, filters have been installed to operate as conventional trickling filters except during the canning season, when they operate as high-rate filters with large amounts of effluent re-circulated.

The flocculation effect of high rate filters has been noted by various observers. A recent study (232) of the results of the operation of experimental filters by Levine and associates (139) shows that filtra-

tions at 8 and 16 m.g.a.d. rates so modified the colloidal matter that 82 per cent as much B.O.D. was removed in the final sedimentation tanks as by the filter unit.

Imhoff (111) considers that less sludge is digested within the high-rate filter and larger amounts of a more putrescible sludge are discharged and removed by final sedimentation than with low-rate filters.

Notwithstanding the large amount of development work done during the past three years with high-rate trickling filters, including recirculation and stage filtration, much additional research will be required before the economical utilization of these procedures may be definitely established with all types of sewage. The low-rate filter still attracts the attention of the conservative engineer where an assured high degree of sewage treatment is desired.

The efforts of a number of commercial firms to establish the patented high-rate filtration process, coupled with the desire of many industries to find the most economical process of biological treatment of industrial wastes, gives promise of a continued activity toward the utilization of high-rate filters.

An interesting structural development has been the elliptical concrete domes 150 ft. in diameter to cover trickling filters at Hibbing, Minn. (158). Shell thickness varied from 3½ to 6 inches.

Miscellaneous.—Description and results of interchangeable tray filters placed above each other 2½ in. apart are given by Demoll and Liebmann (40). Large protozoa were predominant in the upper trays; smaller forms and numerous small worms in the center. General biological activities increased greatly so that the rate of application could be increased several times as compared with ordinary filters.

Steel (235) gives some results on contact aeration. Contact media was crushed stone 2 to 3 in., concrete cylinders 2 in. in diameter and corrugated aluminum plates. With a B.O.D. of 108 to 116 p.p.m. in the pre-settled sewage, the effluents from contact filters had a B.O.D. of 7 to 14 p.p.m. The contact aeration was applied in two stages each followed by sedimentation. Amount of air used was 1.25 to 1.8 cu. ft. per gallon. Certain advantages over activated sludge treatment are claimed.

At Wellington, Ohio (14), settled sewage is run into a sodded area. The grass strains the solid matter, acting as a colloider or contact surface. Beach grass was found suitable for this purpose. Underdrains were provided.

Melbourne, Australia, has in operation 967 acres of grass filters, according to Borrie (25). Settled sewage passes through graded bays 33 ft. wide and not less than 120 ft. long which are sown with Italian rye or native buttonweed. Effluents with as low suspended solids as 5.2 p.p.m. and B.O.D. of 17.8 p.p.m. were obtained from well established grass areas, receiving settled sewage with suspended solids of 164 p.p.m. and B.O.D. 363 p.p.m. Uniform continuous loading of 1 m.g.a.d. per 20 to 24 acres is practiced. No odor or other nuisances are reported.

Activated Sludge

Mechanism of Process.—The rate of oxygen consumption by activated sludge under different conditions has been the subject of a number of investigations. Sawyer and Nichols (207) observed that at least three types of curves can be drawn from the oxidation of various activated sludge-sewage mixtures but that approximately the same type of curve can be expected from any sludge when oxidizing different domestic sewages. They believe that the utilization of oxygen by activated sludge at a rate greater than 7 mg. per hour per gram of dry sludge indicates a poor sludge. This is in agreement with the findings of Ruchhoft, McNamee and Butterfield (195), who considered sludges using 2 to 6 mg. of oxygen per hour per gram of sludge as good sludge. Sawyer and Nichols found good correlation between the base rates of oxygen usage (utilization by sludge alone) with the percentage of volatile matter in the sludge. They also reported that the amount of oxygen consumption per unit of time by an activated sludge-sewage mixture is influenced by the strength of the sewage, as measured by the B.O.D. Sawyer (206) showed that the high initial rate of oxygen utilization by certain activated sludge-sewage mixtures is caused primarily by oxidation of nitrogenous substances and that the duration of the high rate can be prolonged by addition of substances containing readily available oxidizable nitrogen such as urine, urea, ammonium chloride or peptone. The addition of soap or glucose to such mixtures did not prolong the period of high oxygen usage. The high initial rate of oxygen utilization by an activated sludge-sewage mixture, in which nitrification was a minor factor, was found to be caused by oxidation of carbonaceous matter. The high rate was prolonged by glucose in proportion to the amount present but soap or peptone did not appear to have a similar effect. From these observations Sawyer concluded that the duration of the initial high rate of oxygen utilization by activated sludge-sewage mixtures was related to specific components of the sewage in the cases studied, rather than to the combined effects of all the components. Sharp breaks in the rate curves usually indicated the completion of the oxidation of one component. Although oxidation of sewage by activated sludge has been considered as progressing in two stages, the author believes that the oxidation, first, of carbonaceous material and second, of nitrogen, is not necessary. If nitrifying organisms are present and ammonia nitrogen is available, production of nitrites and nitrates may begin in the first part of the aeration tank.

Sawyer and Rohlich (210) found that temperature influenced fairly constantly the rate of oxygen utilization by activated sludge and by activated sludge-sewage mixtures obtained from four different sources under summer and winter conditions. For activated sludge alone, the average rates at 20, 15 and 10° C. were found to be 71.2, 45.2 and 25.5 per cent, respectively, of that found at 25° C. Activated sludge-sewage mixtures gave rates of similar magnitude which averaged 73.4,

46.1 and 24.0 per cent of that found at 25° C. They have developed an equation $y = 0.71\ x^{1.84}$ in which y is the relative activity in percentage, based on the value at 25° C., taken as 100 per cent, and x is the temperature in degrees centigrade. This equation has been found to apply in general to the influence of temperature on the rate of activated sludge oxidations. Temperature has the same effect on rates of nitrogenous and carbonaceous oxidation. Winter sludges were found to use more oxygen at a given temperature than the corresponding summer sludges. This variation has been correlated with the compensating ability of activated sludge to overcome, partially, the influence of seasonal temperature changes.

Ruchhoft, Butterfield, McNamee and Wattie (196) presented data to show that the rate of removal by activated sludge of total carbonaceous (first stage) B.O.D. of the substrate, which may be sewage or some other nutrient substance, is very high for the first half hour. The high rate may continue as long as three hours. From 80 to 90 per cent of this first stage B.O.D. can be removed from the sewage substrate with five hours' aeration. The proportion of this first-stage B.O.D. reduction actually oxidized varies from 2.5 to 30 per cent in 30 minutes and the values increase to 30 to 60 per cent after 5 hours. The variations depend upon the quality and quantity of both sludge and sewage in the aeration mixture. The percentage of first-stage B.O.D. removed from the sewage as a result of net adsorption and synthesis (all mechanisms other than oxidation) increases rapidly from the start for from 0.5 to 3.0 hours, and during this period a maximum of about 50 to 70 per cent is removed. After the maximum was reached, the net percentage of first stage B.O.D. removed by adsorption and synthesis decreased.

Ruchhoft and Smith (197) reported that short time utilization tests are the best index of change with overloading or starvation of activated sludge. The quantity of oxygen used per gram of suspended solids during short aeration periods of mixed sewage and sludge samples gradually increased with overloading of sludge. When the addition of sewage to the sludge was stopped, the oxygen consumption slowly decreased. Their experiments indicated that the biological quality of activated sludge gradually deteriorates with prolonged overloading or starvation. Prolonged aeration without food altered the normal characteristics of activated sludge to a point where the sludge entirely lost its ability to oxidize sewage at high rates.

Heukelekian and Littman (98) in studying the carbon and nitrogen transformations in the purification of sewage by the activated sludge process, found that with short periods of aeration, such as an hour, the carbon of the sludge increased by adsorption at the expense of the suspended organic carbon in the liquor. The removal of the finely divided organic carbon which followed was attributed to biological assimilation by sludge floc, as it was accompanied by a high rate of CO_2 production. This rapid removal of organic carbon from suspension and the slower removal of the finely divided organic matter by

oxidation resulted in an increase in the amount of sludge, first by physical accretion and then by microbial assimilation. Continued aeration beyond the purification period resulted in dispersion of the sludge accompanied by an increase of organic carbon in suspension and liberation of the end products of bacterial metabolism with an increase in finely divided organic carbon. About 65 to 75 per cent of the organic carbon removed by activated sludge could be recovered as CO_2. The nitrogen transformations were (*a*) quantitative conversion of ammonia nitrogen to nitrate, (*b*) bacterial assimilation of some ammonia nitrogen and (*c*) liberation into the liquor of part of the nitrogen as ammonia with periods of overaeration and then conversion of the ammonia to nitrates. The carbon to nitrogen ratio of activated sludge was approximately 5.7 to 1.

Heukelekian and Littman (99) also studied the morphological and cultural characteristics of cultures of zoogleal bacteria obtained from 14 different activated sludges. These cultures, capable of producing flocculent masses simulating good natural activated sludge, were found sufficiently alike to be classed either as one species or as one genus and were also indistinguishable from the zoogleal bacterium, *zoogloea ramigera*, described in 1935 by Butterfield. Sludges prepared from pure cultures of these organisms settled rapidly and had an average index of 54. These pure culture sludges were stable and could not be made to bulk under conditions which would produce extreme bulking of natural activated sludge. The chemical composition of pure culture zoogleal sludges was fairly constant. On the average, they contained 44.9 per cent carbon and 9.9 per cent nitrogen. The carbon to nitrogen ratio was 4.5 to 1.

Sludge Bulking.—At Manchester, England (148), bulking of sludge was found to be caused not by change in pH, lack or excess of oxygen, presence of filamentous organisms or excessive grease but it seemed to be a result of a normal decrease in density of the sludge, experienced during dry weather, and a lowering of the critical weight of the sludge. At times, bulking seemed to depend on the nature and concentration of industrial wastes in the sewage. A reduction in the volume of return sludge was suggested to improve settling.

Bulking occurred when settled sewage instead of raw sewage was added to the aeration tanks at Shanghai (215). The addition of silt or mud was only partially successful in eliminating the trouble.

At San Antonio, Berg (21) reported that the addition of too much digester supernatant liquor to the primary clarifiers seemed to be the cause of bulking. When activated sludge is in good condition, quite a large amount of digester supernatant liquor is required to poison it and to produce bulking. If the sludge is in poor condition because of slight under-aeration it is sensitive to even small amounts of digester liquor. Twice, when a tank was poisoned, several months elapsed before the sludge index dropped to a satisfactory value and then only after decided increase in the amount of air per pound of B.O.D. load.

The presence of large amounts of filamentous organisms has frequently been blamed for bulking of sludge. Rarely, indeed is bulking ascribed, even in part, to the absence of these organisms. In the treatment of whey washings by the activated sludge process the British Water Pollution Research Board (253) reported that bulking occurred on several occasions. This bulking, they believed, was probably caused by the breaking up of flocs, facilitated by the absence of filamentous organisms, and to a change in the character of the bacteria which did not readily form zooglea.

When Ingols and Heukelekian (114) studied the effect of carbohydrates on the bulking of sludge they found that, with a relatively large amount of carbohydrate, such as glucose, and a limited amount of nitrogen, the zoogleal organisms could not completely utilize the carbohydrate and leave an excess to stimulate the growth of *sphaerotilus*. With an abundance of nitrogen and fairly large amounts of glucose the zoogleal organisms can compete with *sphaerotilus* only for a short time since, in the presence of glucose the *sphaerotilus* develops at a much higher rate than the zoogleal organisms. The optimum carbon to nitrogen ratio to retard bulking is approximately 8 to 1. The condition of the sludge, defined as the stage of oxidation of the sludge and indicated by the nitrate content, is also important and may affect bulking by a shift in the flora, such as a decrease in numbers of *sphaerotilus* in well oxidized sludges and by oxidation-reduction phenomena. These generalizations are based on the facts that zoogleal organisms cannot be made to bulk under conditions which ordinarily induce bulking and that zoogleal organisms are strict aerobes while *sphaerotilus* is a facultative anaerobe.

American Design and Practice.—Regester (185) has presented pertinent data relating to the basic design and principal characteristics of thirty plants with large and medium capacities for comparative study. He included operation results for some of the plants.

King (128) discussed the design of air distribution systems for activated sludge. He pointed out that the cost of providing compressed air for an activated sludge plant over a period of from two to five years usually exceeds the first cost of the entire air distribution system. From 10 to 35 per cent of the cost is caused by pressure losses in pipes and diffusers. These losses are reduced by increasing the sizes of air pipes and the number of diffuser plates. In Chicago, increasing the number of rows of plates made little difference in the efficiency of treatment but less air pressure was required. Although it is theoretically possible to design an air piping system to give equal pressure to all diffuser plates without throttling valves at the plate connections, actually standard pipe sizes must be used and the throttling of valves at the plate connections is the most practical method.

Howson (106) reported on the design of a plant under construction at Gary, Indiana where the air is to be distributed through stationary diffusion tubes, 3 in. in diameter and 24 in. long. The tubes, which have a permeability of 40, are staggered along the header so as to give

a spacing of 1 ft. 4 in. There will be 225 tubes placed 2 ft. above the bottom in each 300 ft. tank. The fixed tubes were selected instead of plates because of a saving in initial cost and some saving in annual cost, as a result of decreased head, and because of the advantage during periods when the tanks are out of service as will frequently be the case in Gary in the early years.

A modification of the submerged contact aerator for small cities has been proposed by Hayes. According to Rainey (184) a plant consisting of two hopper-bottom aeration tanks in series has been in operation at Waco, Texas for five years. The first tank, divided into two equal parts by a submerged weir, contains vertical sheets of aluminum spaced 2 in. apart, connecting the side walls and extending from 2 in. below the water surface almost to the bottom of the side walls. The second tank, which is also divided in two, is filled with 2½ to 3 in. stone, supported on a bottom grill of steel rails. A total of about 1 cu. ft. of air per gallon of sewage is supplied to the tanks through pipes in the bottom. It is claimed that the process requires one-half the space and power and costs two-thirds as much as activated sludge. This contact aerator, which is said to deliver an effluent as good as from the activated sludge process, is especially recommended for milk, brewery and other trade wastes.

The Sanitary District of Chicago (244) is approaching completion of the program to treat all the sewage in its territory by artificial processes. The Southwest activated sludge plant, the world's largest, which was designed for an average flow of 400 m.g.d. from a population of 1,227,000 and an industrial waste equivalent population of 1,185,000, was put into operation in July, 1939.

New York City's program for sewage treatment is gaining momentum with completion of the Tallmans Island activated sludge plant (72), capacity 40 m.g.d., in April, 1939 and the opening of the Bowery Bay plant, capacity 40 m.g.d., for primary treatment, in October, 1939. It is expected that the activated sludge tanks will be in operation late in 1940.

Foreign Practice.—The new sewage treatment plant for Delhi, India, described by Bromage (27) consists of preliminary sedimentation (1.5 hr. detention) and activated sludge (12 hr. aeration). The aeration tanks are made up of 108 pockets each 30 ft. square and in the center of each pocket is an uptake tube of reinforced concrete. At the top of each tube is a paddle wheel on a vertical shaft, co-axial with the uptake tube. These paddles draw the contents of the pocket up the tube and throw them, in a finely divided state, over the surface of the tank liquor. Suitable baffle walls are provided to guide the sewage through a sinuous course and obtain maximum aeration. The aeration paddles are suspended from gear boxes mounted on concrete bridges and each is provided with a clutch for throwing any paddle out of operation without disturbing the rest of the plant. At the outlet end of the aeration tanks are adjustable weirs so that liquid level and cone submergence can be varied.

Rudolfs and Kessener (204) have reported on some of the new developments in sewage treatment in Holland. The new type of Kessener aeration brush is made of a rustless steel axis and narrow thin blades which are caulked cold with a hammer in lead and placed in slots of the axis. The blades are very flexible, have a long life and can be replaced easily when necessary. At the Hilversum works, the activated sludge is returned by means of water wheels which allow any given amount of sludge to be returned by raising or lowering the depth of sludge in the return sludge channel.

The new Vught activated sludge plant with the Kessener surface aeration system is designed for an ultimate population of 25,000 and operates entirely automatically. One man visits the plant on Monday mornings to take meter readings, oil machinery and draw sludge from the digesters.

A comparison was made at Stockport, England, between the Kessener brush system and Haworth paddle units under both summer and winter conditions. According to Ward (250), the Kessener units showed a saving of 33 per cent in power and delivered a better effluent than did the Haworth units.

Sludge Digestion

Relatively few articles pertaining to the digestion of sludge have appeared in the technical literature during the past year. Reports on research projects have been notably lacking. Most of these were concerned with the interesting possibilities of controlling and hastening digestion by means of prepared cultures, and with the effect of digestion on the production of fuel oil by the dry distillation of the residue.

The trend of plant design and operation is still toward two-stage digestion with increasingly greater demands for power generation and the provision for adequate safety means in the gas collection and utilization system.

Research.—Heukelekian and Heinemann (94, 95) have reported on a method of enumerating methane-producing bacteria in sludge undergoing digestion. They indicate that the number of these bacteria is greatly affected by environmental factors, such as pH value, temperature and the presence of certain organic compounds, and is indicative of the rate and course of digestion. The same authors (96, 97) stated that an enriched culture of these organisms may be prepared, which when added to raw sludge will greatly accelerate the rate of digestion. Whether such a procedure is economically feasible has not, however, been shown.

Sibata (218, 219) in continuing his work on the distillation of sludge, reported yields of "fuel oil" in the distillate of raw primary, raw activated and digested activated sludges as approximately 12, 17.5 and 10 to 15 per cent, respectively. In the case of the digested activated sludge, the yield decreased with increased periods of digestion. The same author (220, 221) stated that air dried primary sludge gave 8.5 per cent crude oil and 5.8 per cent washed fuel oil. The latter yielded

about 23 per cent gasoline. In general, yields from activated sludge are greater than from primary sludge. As a short period digestion (30 days) decreases the yields but little, digestion of sludge is preferred because of the supplementary gas obtained which may be used as fuel. This work is of interest because of the new field of investigation it presents. Whether it would have commercial possibilities is questionable, at least at this time in the United States, because of high operating costs.

Rudolfs and Gehm (201) have presented data on the chemical treatment of mesophilic and thermophilic digesters overflow liquor. Ferric chloride or lime treatment effected good clarification in each case. Chlorination was not effective on thermophilic tank liquor.

Design.—Hodgson (103) presented in his valuable 534 page report on sewage and trade waste treatment, a comprehensive review of modern digester design practice in the United States, Great Britain, Holland and Germany. This report is a veritable text book, not only on sludge digestion but on sewage treatment in all its phases. It is unfortunate that because of its high cost its distribution has been limited. Greeley (75) discussed design practice as pertaining more particularly to the United States. Details of operating loads, inlet and outlet arrangements, etc. are briefly discussed. Escritt (59) gave methods of computing digester volume, heat requirements and sludge volume reductions. Fischer (61) suggested that pre-thickening of activated sludge either by the use of separate thickeners or the return of the waste sludge to the raw sewage reduces the digester volume requirements. Thompson and Morrill (241) described in detail the new Detroit digesters where primary sludge solids loadings as high as 6.0 lb. per cu. ft. per mo. may be used. Howson (106) described the Gary two-stage digestion system for digesting mixed primary and activated sludge.

Many arteiles were presented on the aspects of gas collection and utilization in relation to digester design. Of these, the discussion by Wittwer (263) was outstanding because of its complete analysis in regard to gas storage, scrubbing, economics, etc. as applied to Rahway Valley, N. J., conditions. Suggestions for minimizing explosion hazards around digesters were presented by the N. J. Joint Committee (168) and also by Keefer (124), and by Klumpp (129). Although a number of these call for "horse-sense" on the part of the operator, such design points as adequate size of gas lines, proper interconnecting of gas holders with digesters, etc are interesting design points.

The design of sludge tanks at Tallmans Island is described by Liebman and Fort (141). There are four digestion tanks with floating covers with a capacity of 2.43 cu. ft. per capita. Temperature will be maintained at 85° F. with circulating water obtained from waste engine jacket supplemented when necessary from boilers heated by sludge gas. Digested sludge will be barged to sea.

The design features and four months of operation results for the new Hartford Metropolitan Plant are reported by Wurts (264). The

novel feature of the digestion tanks is the insulation. The tanks were built above ground and without an embankment. Aluminum foil was used as insulating material. The reduction of volatile matter during a 30-day digestion period was 70 per cent with a gas yield of 0.54 cu. ft. per capita per day.

A gas production of 1.4 cu. ft. per cap. per day was reported at Battle Creek (10) with 65 per cent methane. Only half of the gas is used for running gas engines and heating the boiler, the rest being wasted. The value of the gas in terms of electrical energy is given.

Lansing (8) is digesting primary and activated sludge and garbage in four digesters with fixed covers. A De Laval centrifuge is installed for the purpose of concentrating activated sludge prior to digestion. Garbage delivered at the plant will be ground in hammer mill grinders and delivered directly to the digesters with a moisture content of 75 per cent. The gas will be used to drive gas engines for compressing air and gas-engine cooling water will be circulated through digesters.

Taylor (240) describes the operation of combined sewage treatment and refuse incineration plant at Herkemer, N. Y. Sludge gas is used as auxiliary fuel in the incinerator. Water coils in the furnace and combustion chamber absorb the heat from the gases of combustion. The hot water thus obtained is used to heat the building and the digestion tanks.

Operation.—Sperry (230, 231) emphasized the need of introducing a concentrated raw sludge into digesters to secure good operation where two-stage digestion is employed. This applies to single-stage as well as multi-stage operation. The work at Aurora aptly illustrates that operating errors may occur even where close supervision is maintained. It also shows that an intelligent review of complete plant records aids greatly in overcoming operating difficulties. Riley (191) reported extreme fluctuations in digester gas as metered from 400 to 23,000 cu. ft. per day, the low figures being probably due to numerous leaks in the collection system. The need is emphasized for carrying the gas lines to the point of gas utilization through a gallery rather than burying the lines in the ground.

Patents.—Earp-Thomas (50) has a British patent for a multiple-hearth type digester for the aerobic digestion of organic material, such as raw sludge filter cake. The claims are limited to specific construction details. Roeder (193) also described an apparatus and a process for stabilizing sludge aerobically. Stabilized (digested) end product may be recycled to the raw sewage.

Plant Records.—Complete records were being kept in the form of monthly or annual reports by an increasingly large number of plants. Unfortunately, because of expense, these reports were not made generally available. It would be of immense value to designing engineers and plant operators if more of these reports were published at least in summary form, such as was done in the case of the report of Danbury by Kunsch (137), of Champaign-Urbana by Erickson (58) and of Buffalo by Velzy (249).

Typical among the plants that have compiled monthly or annual reports during the past year in which considerable digester data are tabulated, were—Aurora, Battle Creek, Buffalo, Cedar Rapids, Denver, DeKalb, Ft. Worth, Galesburg, Grand Rapids, Green Bay, Greensboro, Iowa City, Jackson, Lansing, Lima, Mansfield, North Toronto, Peoria, Phoenix, San Antonio, Sheboygan, Sioux Falls, Washington, Winnipeg and Ypsilanti.

Need for Further Study.—Future work on the stimulation of anaerobic digestion by means of additions of cultures should be of interest and of commercial importance if the digestion time can be reduced to say two to five days. Aerobic digestion studies on both settled sludge and on partially dewatered material, such as filter cake, also offer a field for continued research.

Published information is still needed on rational methods of computing digester volume requirements for various types of sludges, heat losses from digesters, proper gas storage requirements, etc. Differences in digested sludge solids concentrations and in overflow liquor solids, occurring at different plants having about the same raw volatile matter contents, have not yet been fully explained. Such questions may be answered only by the maintenance of complete digester plant records and by making these records available so that they may be compared and studied in detail.

Sludge Disposal

In the 1939 inventory of the nation's sewage facilities, Engineering News-Record (13) reports that 3,170 sewage plants out of 4,667 employ sand beds for air-drying sludge. Of these plants, 223 used covered beds. Mechanical dewatering shows a gain from 19 installations to 61 in three years, with an increase from 6 incineration installations in 1935 to 29 in 1939.

Centrifuges are still undergoing development. Hardenbergh (84) reports though some installations have been made, this method of sludge dewatering does not, as yet, seem to be fully accepted by engineers. Fischer (61) states that dewatering of activated sludge by centrifuges must still be regarded as in the experimental stage.

Sludge Drying Beds.—In the annual report of the City of Johannesburg, Loffell (143) gives some valuable experimental results on the factors that affect the drying of sludge on sludge-drying beds. It is pointed out that first, the surface sand should be very coarse and clean. The depth is immaterial. Second, the surrounding walls should be as low as possible offering minimum deflection of wind. Third, the bed should be in an exposed place. The best depth of wet sludge is, in general, six inches. The sludge will be dry enough to remove from the bed when the moisture content has been reduced to 70 to 75 per cent. The effect of rain is not so considerable as generally supposed, if there are dry days immediately following it. The effect of rain varies according to the length of time that the sludge has been on the bed before the rain, having the maximum retarding action when the sludge

is cracking but is still inclined to be sloppy. About 60 per cent of the water drains away in 20 hours. Evaporation increases gradually but its rate of increase diminishes with time. If drainage were prevented, it required 8 to 9 days under the sun to remove the same amount of water as by drainage in one day

At the Rahway Valley plant, Wittwer (262) believes there is little difference in drying efficiency of the open and covered beds. In the summer, the open beds are better, while the balance may slightly favor the covered beds during the fall months. In winter, freezing is depended upon for cake removal from both the open and covered beds.

Hardenberg (84) states at one plant steam will be used for hastening sludge drying on covered beds.

Sludge as Fertilizer.—Of 220 activated sludge plants in the country, digestion is omitted in only 16 plants (61). Thus much of the extra fertilizing value of raw activated sludge is lost. Van Kleeck in a series on vacuum filtration (246) reports fewer bacteria in sludge cake conditioned with lime than are present in air-dried sludges.

Niles (171) draws sludge intended for fertilizer 8 ft. above the lowest level in digestion tanks, to obtain material higher in organic matter and lower in ash. This level also is higher in nitrogen and no grit is present. The sludge is ground, put in paper bags holding 81½ lbs. gross, and sold by the city at an up-town warehouse under the catchname, "Tol-e-Gro." Proper preparation of the sludge and advertising were found to pay.

Allen (2) reporting on the Pasadena Tri-City sewage treatment plant gives the net cost of sludge disposal for 1937–38 as $14,000 when raw activated sludge was dewatered by vacuum filters, dried, pulverized, screened and bagged. A revenue of $63,000 was obtained with a production cost of $77,000. By comparison, in 1926–27, when filtered raw sludge was buried, the net cost of sludge disposal was $54,300.

Barging to Sea.—This means of disposal was instituted at the large Wards Island plant (46) and the Tallmans Island plant (73) in New York. Donaldson (46) states that Wards Island is using three sludge vessels, each having a capacity of 55,000 cubic feet. Three daily trips are made, and raw activated sludge is dumped 34 miles by water from the plant. Odor control is unique. A forced air draft is used in the sludge storage building, this air being drawn through canisters of activated carbon, then dosed with ozone before roof discharge. At Tallmans Island digested activated sludge is barged.

Vacuum Filtration and Incineration.—Johnson (120) Van Kleeck (246) and Vail (245) contributed articles during the past year on the mechanics of vacuum filtration. Johnson quoting experiences of the Sanitary District of Chicago with raw activated sludge states that the main factor contributing to maintenance costs is the cloth. The most successful cloth at Chicago has been a virgin wool twill weave, weighing 12 oz. per sq. yd., woven in one piece without seams, and with a nap on one face. At the Calumet Works from 1,000 to 1,500 hours of filter run has been obtained without renewing cloths. The control of the

ferric chloride dose has been based until recently on pH readings manually determined. A recorder was purchased a short time ago and savings in chemical are anticipated (19).

Van Kleeck (246) described vacuum filter operation in detail, including a discussion on care of cloths, laboratory control, sludge conditioning, design of filter lay-outs, and presented comparative arguments for filtration of raw and digested primary sludges. Formaldehyde or copper sulphate solutions were suggested for prevention of cloth mildew. A titration method for determining ferric chloride solution strengths is given. The Buchner funnel and pH tests as a control of sludge conditioning are discussed and recommended. He believes digested sludge filtration is the better set-up for medium-sized plants.

At New Brunswick, Vail (245) found that when ferric chloride is used alone for conditioning digested sludge, considerable foaming occurred. When lime was also used, foaming was controlled and the ferric chloride dose reduced from 5 per cent (dry solids basis) to 0.4 per cent. The lime also caused a further decrease in cake moisture.

Governing principles of flash-drying and incineration were ably presented by Smith (227) and Reybold (188). At Chicago (7) steam will be generated in connection with sludge incineration for driving turbine equipment. This system has resulted in a saving of nearly 50 per cent in the first cost of the Southwest activated sludge plant and the operating costs are expected to be about a quarter of a million dollars less per year with this method of sludge disposal. Tenafly, N. J. (227), has installed a lay-out utilizing heat from a refuse incinerator for flash-drying raw activated sludge. Plans include the burning of the dried sludge in the refuse incinerator or its use as fertilizer.

Detroit's answer to a 30-year pollution problem (241, 198) includes four multiple hearth incinerators, each having a capacity of 300 tons of wet cake per day. A filter drum area of 8,000 sq. ft. will be provided for furnishing sludge cake to the furnaces.

Schroepfer (214) in describing raw primary sludge disposal at Minneapolis-Saint Paul points out: (1) Proper mixing and agitation of conditioned sludge prior to filtration is of utmost importance, especially with heavy sludge. (2) The quantity of chemicals required for sludge conditioning is less with heavy sludge. (3) Holding raw sludge for seven days did not increase the chemicals required for conditioning or appreciably affect the filtering rate, but odors were more pronounced. (4) Plans are under way for the continuous control of sludge filtration by the filter operators themselves by means of Buchner funnels. (5) Chemical costs for sludge conditioning have been reduced $100 per day since the plant started in operation. This reduction was accomplished by various means. (6) Using ferric chloride without lime for sludge conditioning was not economical. (7) It is cheaper to use less chemical and have a lower filter rate. (8) A reduced lime dosage has materially increased the filter cloth life. (9) Raw sludge storage facilities are very desirable.

Velzy (248) has recently described filtration and incineration at Buffalo with digested primary sludge. The sludge tanks, he states, have been a definite asset. The tanks provide a flexibility and smoothness in operation which could not otherwise be obtained. The gas produced has real value as fuel for heat and auxiliary fuel for incineration. He suggests the use of a sludge cake surge bin and feeder to even out variations in filter yields. Furnace operation is thus simplified.

W. H. Dundas (48), engineer of mechanical design, Sanitary District of Chicago, has presented data for consideration in the incineration of sludge and screenings. Data are included on the operation of the Calumet and Southwest disposal plants of the city of Chicago.

Mohlman (157) commenting editorially on the above articles points out that differences in filtrability of the sludges are not so much due to mechanical equipment as to type of sludge. Activated sludge filter cake contains nearly three times as much water per unit of solids as raw or digested primary sludge cakes. Comparative tables in the editorial of the sludges at Minneapolis, Buffalo and Chicago are of interest.

Centrifuging.—The concentrating of activated sludge is important in facilitating its disposal. Kraus and Longley (135) reported on the operation of a continuous vertical shaft centrifuge, 18 in. in diameter, driven by a 10 hp. motor at about 6,000 r.p.m. It was possible to increase the concentration of solids from 1 to 5 per cent. The return to the aeration tanks of the centrifuge effluent, which contained about 2,500 p.p.m. of suspended solids, did not greatly affect the operation of the activated sludge plant or seriously interfere with centrifuge operation but it did increase the sludge index. Assuming an initial activated sludge concentration of 1.0 per cent solids, the maximum rate of feed to obtain reasonable concentration of solids and fair clarification was 1,800 gallons per hour. Sludges with more than 1.0 per cent solids must be fed at a slower rate and thinner sludges can be fed at a higher rate but not inversely proportional to the solids content. The average power consumption was 9.3 kw. and the total cost of concentrating sludge from one to five per cent was $5.79 per ton of dry solids. They state that the gritty substances in primary sludge and in digested primary and activated sludge interfere with satisfactory operation of a centrifuge.

Promising results were obtained with a centrifuge at Manchester, England (148) where sludges were concentrated to 5.3 per cent solids. However, it was believed that a sludge with 3.5 per cent solids was most desirable, as a considerable reduction in volume was obtained and the resulting sludge was not too viscous to pump. Slowly rotating vertical screens seldom concentrated sludge to 2.0 per cent solids.

Sludge Elutriation.—Keefer (123) in an article describing the $2,000,000 improvements at Baltimore Back River Works states that wash water for elutriation of digested sludge will be obtained from the trickling filter effluent. Chlorinated copperas will probably be used as a sludge coagulant.

Wurts (264) described sludge elutriation for the new Hartford Metropolitan plant, this being the second largest plant in the United States to begin operation with the process.

Comparative filtration tests with elutriated and unelutriated digested solids were presented by McNamee (153) with an interesting discussion by Genter. McNamee attributes the success of elutriation largely to the removal it affords of the ammonium bicarbonate from the sludge mixture. Counter-current washing with 2½ volumes of water to 1.0 of sludge permits digested sludge filtration at Washington with one-third the amount of ferric chloride that would otherwise be required. McNamee finds that the alkalinity test is a convenient measure of the degree and completeness of a sludge elutriation.

Genter in the discussion holds that the paper's conclusions should satisfy those who maintain it has not been shown that the soluble decomposition products, produced during digestion, are largely responsible for the resistance of sludge to coagulation. About 90 per cent of the ammoniacal bicarbonate solute can be removed by elutriation.

Sludge Dewatering by Freezing.—Downes (47) has called attention to the well-known fact that sludge after freezing dewaters very readily on thawing. The probable reason, he states, is a breaking up of the cellular structure. He believes power for practical refrigeration of the sludge can be produced from the sludge gas and a full-sized unit is proposed in the near future at the Joint Sewage Treatment Works of Plainfield, Dunellin and Bound Brook, N. J.

Miscellaneous.—A novel plant at River Falls, Wisconsin, is described by Halvorson and Smith (81). One thousand gallons of 3 per cent solids raw sludge obtained daily from a connected population of 3,000 is conditioned with ferric chloride and copper sulphate in a lightning mixer, producing 1,500 to 1,800 pounds of 80 to 85 per cent moisture sludge cake after 6 hours drying in a housed sand bed. The cake pulverizes easily, the bacterial content is markedly reduced, it contains 3½ to 4 per cent nitrogen (dry basis) and is used as a fertilizer. It is stated that the plant operates without flies or odor.

Lloyd and Stehli (142) have patented a method of sludge treatment whereby the wet masses are divided into fragments coated with a dry powdered material and drying gases at a temperature not above 107° C. are passed through air passages left in a layer of the fragments until dry. The sludge is then ground and burned. The gases are used for drying and the ash for coating the wet sludge. The usual method is to use dried and powdered sludge particles for coating.

Chlorination

Many applications of chlorine in sewage treatment practice reported during the past year, are of special significance and importance. As the capacities and uses of chlorine installations are increased, however, the lack of fundamental research in the field of chlorination becomes more marked.

A paper by Beyer (22) provides a new group of basic chlorine reactions according to the purpose for which chlorine is applied in sewage treatment. The development of automatic equipment, utilizing two electrodes for control of the chlorine dose by potential measurements, has been described by Schmelkes (213). This equipment is expected to provide a method of regulating chlorine application in accordance with the demand of the sewage, either for partial or complete satisfaction of the demand.

Franklin (64) reports in detail on successful plant-scale use of chlorine for the cleaning of diffuser plates in the aeration tanks of an activated sludge plant. Intermittent application of chlorine gas to the compressed air line supplying one unit, to a total of 150 pounds of chlorine, was made by means of a direct feed W & T chlorinator. The increase in air delivery which followed such treatment is reported as 66 per cent with one blower in service and 53 per cent with two blowers in service. Data on air delivery six months later showed results to be practically as good as at the conclusion of treatment, and no detrimental effects from the application of chlorine were observed. This treatment was repeated with another unit. The author claims more effective and economical cleaning of clogged diffuser plates by this method.

Chlorine for Disinfection.—The importance of chlorine in disinfection of sewage is indicated by the predominance of installations for this purpose. Symons (238) has reported no further laboratory studies at Buffalo, but does note that the average use of some 4,880 pounds of chlorine per day, while somewhat below the estimated requirements, has consistently produced an average kill of almost 99 per cent of *B. coli* organisms. At the Niagara Falls plant, chlorine may be applied as pre-, split-, and post-chlorine doses according to a description by Rudolfs (200).

The new Detroit plant has as one of its prime purposes removal of pathogenic bacteria. Morrill (164) describes the chlorination facilities which permit application either before or after settling. It is believed, on the basis of preliminary studies, that a minimum of 8 to 10 tons of chlorine per day will constitute a yearly average for 1940. The details of elaborate precautions taken to facilitate safe handling and of precautions against chlorine accidents are of unusual interest in this plant. A W. & T. chlorinator installation of 27 tons per day capacity makes this the largest chlorinating plant for either water or sewage treatment in the world.

Chlorination is included in several of the plants under construction in the New York City system. The consultants Greeley, Marston, and Phelps (74) have reported upon tentative plans which include a more complete degree of treatment for sewage discharged into receiving waters designated as class "A," and chlorination is approved for all sewage discharging adjacent to waters used or to be suitable for bathing. The Bowery Bay plant is to provide short-period activated sludge treatment and chlorination; the 26th Ward plant, will be similar. The

Owl's Head plant will be of the chemical treatment type and will also include chlorination.

Elimination of possible bathing beach pollution seems to be the reason for summer chlorination at many plants. At the Richmond-Sunset plant in San Francisco, Casey (34) describes the provision of pre-chlorination facilities at all times and use of post-chlorination in addition during the bathing season. The plant at Virginia Beach, Va., includes both chemical treatment and trickling filters, with chlorination to protect bathing beaches and shellfish areas, as noted by Johnson (119). Chlorine is applied during five summer months at the Rahway Valley Sewage Treatment Plant for both odor control and final disinfection. Wittwer (262) reports that a dosage of 10 p.p.m. gives a chlorine residual in the effluent at all times despite a relatively long contact period in the settling tanks. The chlorine demand appears to bear a definite relation to the concentration of suspended solids in the sewage. Settled sewage is used to operate the chlorinators in this plant. According to Swope (237) the plant at Waukegan, Ill., uses chemical precipitation and chlorine in summer months.

Chlorine for Control of Odors and Hydrogen Sulfide.—In certain sections of the country, the production of iron chloride from chlorine and scrap iron has proved the logical answer to a need for iron compounds. An improved Universal type of the Scott-Darcey equipment has been developed by Wallace and Tiernan and an installation at Bakersfield, Cal., described by Halfelder (79), is of interest. A variety of purposes may be served—chlorine may be fed for odor control, disinfection, or conditioning of supernatant liquor from the digestion tank; ferrous chloride may be generated and applied to control hydrogen sulfide and retard septic action in the sewer; ferric chloride may be produced and used as a sewage coagulant. Gregory (76) notes the advantageous use of similar equipment at Covina, Cal., where proximity of the sewage treatment plant to dwellings, and re-use of the effluent for irrigation, makes odor control and disinfection imperative.

Data on odor control at twenty-five sewage treatment plants have been reported in a symposium (11). Thirteen of the plants use chlorine for this purpose, with a pre-chlorination dose of 4 to 16 p.p.m. Aside from reducing or eliminating odors, the application of chlorine appears to have some secondary benefits. Among those mentioned are: general improvement in plant operation, better condition of the sewage, improved sedimentation, and reduction in algae growths.

Chlorine for Grease Removal.—The plant installed to use the so-called aero-chlorination method for increasing removal of grease from sewage at the Cleveland, Ohio, Westerly plant was placed in service in 1939, but no operating data are yet available. Limited results using this process at Bellefontaine, Ohio, are reported by Browne (28). At this new plant aero-chlorination precedes settling and treatment of sewage on trickling filters. Removal of a large percentage of the grease and other advantages of this process are described.

The trickling filter process has also been selected at Dallas, Texas, and pre-treatment will include (4) pre-aeration, and aero-chlorination for grease removal in a wholly enclosed and force draft ventilated building. Odors liberated will be removed from the evacuated air in a spray tower. At Boston, Mass., serious pollution of the harbor results from present discharge of over 250 m.g. of raw sewage per day. The grease content causes widespread areas of sleek, the accumulation of grease balls on beaches, and necessitates the closing of bathing areas. The proposed (187) method of sewage treatment comprises aero-chlorination for grease removal, sedimentation, sludge storage tanks, and final disinfection during the bathing season.

Chlorine in Activated Sludge.—It is reported (5) that the use of chlorine, applied to return sludge at the Houston, Texas, activated sludge plant continues successful after use for several years. The treatment is economical and permits higher continuous loadings of units. At the Tallmans Island plant of New York City, Liebman and Fort (141) describe the provision of thickening tanks for activated sludge.

In order to prevent bulking of sludge during its detention in the tanks, chlorinators have been provided to treat the supernatant liquor. No operating data are yet available.

At the Chicago Southwest plant, Trinkaus (244) reports that chlorinated activated sludge effluent is used for condenser cooling in the power plant. Nitrites are at times as high as 6.5 p.pm.—thus increasing the chlorine demand. A daily consumption of 5400 pounds chlorine has been reached, to produce a residual of 0.35 to 0.5 p.p.m.

Other Chlorine Uses.—Reports continue to appear in the literature describing the advantages of chlorinating sewage ahead of its application to trickling filters. At Danbury, Conn., Kunsch (137) points out that the use of 42 lb. of chlorine per m.g. eliminates all carrying odors from the filters and destroys fungus growths both in the pipe lines and in the filter beds.

At Austin, Minn., heavy chlorination of packinghouse wastes has been effective for several years in removing a considerable amount of dissolved proteins and suspended matter. Hansen (83) reports the reduction accomplished in B.O.D. to be from 2000 p.p.m. down to 600 to 800 p.p.m. Suspended matter is reduced from 1900 to about 200 p.p.m. This same treatment process is recommended by Eldridge (56) for small meat packing plants as more positive of results than biological processes.

Mechanical Developments

Outstanding in this field is the completion or near completion during 1939 of several large, completely mechanized plants using and combining fairly new methods with older ones adapted from other fields.

The new Chicago Southwest Plant (244) includes not only the relatively new method of flash drying of sludge but combines it with modern high pressure steam power plant practice, utilizing powdered coal and

the heat from dried pulverized sludge burned in a similar manner. The steam at 425 pounds pressure and 735 deg. F., temperature drives steam turbines direct connected to sewage pumps. The activated sludge plant effluent is used for condenser cooling water intermittently chlorinated to prevent slime formation.

Steam power was selected as more economical than purchased electrical energy for all main power loads.

Such a completely mechanized plant requires carefully planned, well organized, mechanical supervision by trained men. Such organization and training is described by Hageman (78).

Reybold (188) Smith (226) and Dundas (48) have thoroughly discussed the history, theory and description, with diagrams and tables, of the flash method of sludge drying. The procedure yields a product suitable either for use as a fertilizer or as a fuel for incineration to furnish heat for the drying.

The Detroit, Mich., sewage treatment plant (241) although furnishing only primary treatment, is another example of complete mechanization. Raw sludge is to be removed continuously from the sedimentation tanks, that from one tank going through a steam preheater to a floating cover digestion tank designed for 300,000 persons, the remainder going to vacuum filters. Sludge cake with screenings and grit is mechanically conveyed to four multiple hearth incinerators each having 12 hearths. The control of the conveying equipment is interlocking so that stoppage of one conveyor will automatically stop any others feeding it. Auxiliary equipment for the incinerators (198) consist of preheaters, cooling air fans, hot air fans, hot gas fans, and fuel oil burners. Each incinerator has a capacity of 300 tons of wet sewage solids per day at 70 per cent moisture. Ash from the incinerators is to be flushed to a lagoon by a 90 hp., 900 g.p.m. pump at 185 ft. head. Rudd estimates a consumption of 1,500 gallons of fuel oil to start one incinerator when cold to a point of sustained combustion.

Gas from digestion of ⅛ of the total sludge production is to be utilized in combined heavy fuel oil-gas burning boilers for producing steam at 140 lb. pressure, and in a 364 hp. 6-cylinder, 4-cycle engine direct connected to a 240 kw. generator.

Steam from the water tube boilers will run a vertical, non-condensing steam engine driving a 200 kw. generator. Exhaust steam and hot water recovered from the gas engine are for heating purposes.

Tallmans Island Plant in New York (52, 72) is notable for its installation of 3,500 hp. in gas engines. Digestion of raw and activated sludge is expected to furnish a large proportion of the gas, with the deficiency taken from the city gas mains. Control is by pressure regulation.

Liebman and Fort (141) state that the selection of the type of heavy duty, slow speed, multiple cylinder four-cycle engine was based on successful experience with similar engines at Coney Island.

The installation consists of two 800 hp. engines direct connected to 20,000 c.f.m. positive displacement blowers; two 450 hp. engines driving

10,000 c.f.m. blowers; two 350 hp. engines direct connected through right-angle gears to 35 m.g.d. pumps at 39 ft. head and two 150 hp. engines driving 15 m.g.d. pumps.

Varying the speed of the engines gives pumping capacities from 50 to 110 per cent of the rating and blower capacity from 33 to 110 per cent of rating

Other interesting mechanical features of this plant are cone check valves on the sewage pumps and extensive metering of sewage, sludge and air with both indicating and recording mechanisms which were a separate study in themselves.

Mitchell (154) describes a mechanized small plant for 3,800 persons at Paola, Kans., built at a cost of $66,000. The mechanical features are a mechanically cleaned screen, screenings grinder, sewage pumps, circular mechanically cleaned clarifier, plunger type sludge pump on time clock operation, mechanically stirred digestion tank from which the gas is burned in a boiler to heat the digestion tank and control house.

West (254) advises selection based on flexibility and dependability particularly in engines under 125 hp. Large starting torque in some motors lasting only a few seconds requires 25 per cent more available engine power than is required with direct drive.

Peoria, Ill. (144), installed two gas engines in 1936, one 535 hp. directly connected to an existing blower and one 300 hp. driving a 285 kw. generator. The installation includes a gas purifier which removes 105 grains of H_2S per 100 cu. ft., or 91 per cent, for 1.5c. per 1,000 cu. ft. A record of 19 months operation of these engines indicates an annual saving of $31,000 or complete payment of project in five years. The Peoria engines are on a regular maintenance schedule (134) which includes valve grinding, clearance adjustments, measurements for wear, inspection of gaskets, ignition system and oil system.

Greene Bay, Wis. (149), with two engines of 90 hp. and 120 hp. directly connected to generators, earned a net profit of $1,111.15 on a total investment of $72,681.72 in 10 months. Gas consumption was 26.2 to 27.5 cu. ft. per kwh. produced.

A detailed study of existing engine installations with the data applied to the situation at Rahway, N. J. (263), indicated that a two engine installation for approximately $40,000 would produce an annual saving of $2,200. This study indicated the desirability of a gas holder for overcoming sags in gas production. It also indicated the advisability of scrubbing gas which contains over 50 grains of H_2S per 100 cu. ft. to remove this impurity.

At Chicago Heights (16), Ill., serious difficulties were encountered with clogged piston rings, crankcase sludge, sticking valves and clogging of small brass and copper lines due to sulfides in sludge gas. The difficulty was overcome by making and installing three two-stage purifiers containing iron sponge (wood shavings and iron oxide) with piping arranged for several combinations of the units. One bushel of iron sponge containing 9 pounds Fe_2O_3 will remove 60,000 grains H_2S. One bushel of sponge occupies 1.25 cu. ft.

The cost of operation was 1.5c. per 1,000 cu. ft. of gas containing 100 grains H_2S, not including labor of replacement. The spent sponge may be rejuvenated and reused two or three times by removing and exposing to the air but care must be exercised to wet the material before removal to prevent spontaneous combustion.

At Bedford, Ohio (145), a gas boiler was installed with oil burner and gas burner on opposite ends automatically controlled to start the oil burner on gas failure. Soot from the oil burner clogged the ports of the gas burner, after which both burners were installed at one end. Operating experience even then indicated the desirability of separate boilers for gas and oil.

At Greenwich, Conn. (77), gas and coal in one boiler proved difficult to control, draft conditions were different for the two fuels and on several occasions minor explosions of unburned gas ignited by coals blew open the boiler doors. Studies indicated danger in trying to install an oil burner in the same boiler but indicated that manufactured gas could be automatically controlled by pressure regulators to make up any deficiency in sludge gas and burned in the same burner, subject to the same safety and limit controls. The first installation was so satisfactory that it was repeated with minor changes in a larger plant being revised. Although for equivalent heat value the manufactured gas costs slightly more than oil, about ten years will be required to overcome the difference in cost of installation. These installations were for industrial type burners and water-tube boilers but further investigation indicates that the same system can be used on regular gas boilers provided a ribbon type burner is substituted for the usual raised port burner.

It is reported (6) that in England sludge gas from the Mogden plant is to be compressed into cylinders for use on motor vehicles. It is estimated that 150,000 cu. ft. of 70 per cent methane gas is equivalent to 700 gallons of petrol (gasoline) per day. The same article also reports that in 1938 approximately one million cu. ft. of purified sludge gas was employed in motor vehicles in Germany.

Industrial Wastes

The literature of the past year contains a large number of excellent surveys of industrial waste treatment which can be given only brief mention. Papers of this type given at the Industrial Waste Symposium of the American Chemical Society at Boston in September include those of Weston (256) on stream pollution by industrial wastes, Tobey (242) on legal aspects of industrial waste problems, and Howe and Van Antwerpen (105) on the recovery of valuable materials from industrial wastes. Developments in equipment for the treatment of industrial wastes were described by Knowles (132).

The use of biological processes for treating organic wastes was discussed by Buswell (30). Comparing anaerobic and aerobic biological methods, he found the former, combined with final aerobic stabilization if necessary, to be cheaper for most wastes containing over

one per cent of organic solids. A special tank was devised for the digestion of coarse materials. Buswell and Hatfield (31) have also issued a bulletin describing ten years' study of the anaerobic fermentation of wastes. Other papers given at the American Chemical Society symposium are treated under their specific headings.

A survey of the Chicago Sanitary District, described by Mohlman (156) showed the industrial wastes to be equivalent to the sewage of 2.32 million persons. Methods of assessing cost of industrial waste treatment are discussed in the paper.

The bulletin issued by Eldridge (54) contains comprehensive data for the design of plants for treating various industrial wastes. It is based principally upon work of the Michigan Engineering Experiment Station, previously reported in these summaries.

Beet Sugar Wastes.—Devos (41) described the recovery of sugar from pulp and press waters by treatment with lime (400 to 800 p.p.m) followed by filtration and re-use of the water.

Brewery, Distillery and Yeast Plant Wastes.—Boruff (26) has described the methods in use for the disposal of wastes from the fermentation industries. Use of these wastes as a source of vitamins, glycerol, and other specialty products is being investigated.

During operation of a pilot plant at the Gulf Brewing Company, Bushee (29) found the average quantity of waste produced to be 350 gallons per barrel of beer, containing 1.1 lb. suspended solids and 2.4 lb. B.O.D. The treatment adopted on the basis of the pilot plant work consisted of two-stage sedimentation, trickling filters 6.5 ft. deep, dosed at a maximum rate of 12.8 lb. 24 hr. B.O.D. per 1,000 cu. ft., final sedimentation and, if necessary, chlorination of effluent. Sludge, amounting to 12,200 gal. per million gal. of waste, is to be digested and dewatered on sand beds. Mohlman's (155) investigation of Chicago brewery wastes showed the quantity of waste to be 320 gallons per barrel of beer, containing 1.7 lb. of suspended solids and 3.1 lb. of B.O.D. Stecher's (234) study of Munich brewery wastes showed a volume of waste averaging 1,030 gallons per barrel of beer and containing 2.2 lb. of suspended solids and 4.5 lb. of B.O.D.

Zimmerman and Greene (7, 266) advocate disposal of brewery and distillery wastes by fermentation at 55 to 65° C. by *Cellulomonas thermophilus,* and sedimentation of the fermented wastes.

Cannery Waste.—Further experiments by Eldridge (55) on screened beet waste resulted in the adoption of coagulation by lime alone, at the rate of 9 lb. per 1,000 gal. Sludge volume was 30 per cent of waste, the sludge drying in 4 days at a 7-inch depth. Tomato waste, treated with 800 to 1,000 p.p.m. of lime, both by fill-and-draw and continuous flow processes, gave a final B.O.D. of about 1,000 p.p.m., and sludge volumes of 22.5 per cent for fill-and-draw, and 13.4 per cent for continuous operation. Squash wastes did not respond to chemical precipitation; the concentrated waste from skinning and seed-removing operations was dried directly on sand beds; the remaining weak wastes were merely screened.

Work on screened cannery wastes in Wisconsin, reported by Warrick (251) comprised studies on chemical precipitation and treatment by a recirculating filter providing six passages of the waste at 20 m.g.a.d. Beet canning waste gave an oxygen demand reduction of 59 per cent when treated with lime and ferrous sulfate, and 85 per cent with lime and zinc chloride. The trickling filter, followed by sedimentation, gave 60 to 75 per cent B.O.D. reduction. Corn waste, treated by lime and ferrous sulfate, the latter in several steps, lost 60 per cent of its B.O.D., giving a water-white effluent. Treatment on the trickling filter, with no final settling, provided a B.O.D. reduction of 70 per cent. Lime and alum gave the best results with tomato waste, and trickling filter treatment without final sedimentation reduced the B.O.D. by 65 per cent. Carrot waste responded to lime alone, or lime and ferrous sulfate, with some agitation, giving 75 per cent B.O.D. reduction. The pH of chemical-treatment sludges should be 9.6 or higher to secure rapid drying. Screening of cannery waste through a 40-mesh screen should precede all treatment proceses. A detailed report on the studies conducted at various canneries in Wisconsin during 1938 and 1939 has been prepared by Warrick, McKee, Wirth, and Sanborn (252).

Chemical Manufacturing Waste.—The waste disposal plant of the Dow Chemical Company at Midland, Mich. (previously described in this JOURNAL, **10**, 1093, 1938), has been discussed by Harlow (86); brine disposal by pumping to underground formations failed at this plant, and recourse was had to impounding and release at high-flow periods. Surveys of brine distribution in Saginaw Bay furnished information for the control of brine release.

Gas Plant Wastes.—Key (127) has published an extensive report on the disposal of gas plant waste, including alterations in plant practice to reduce the quantity of waste. Chulkov and Parini (36) proposed treatment of the de-ammoniated liquors by saturation with chlorine, filtering off precipitated sulfur and chlorophenols, and passing the filtrate through activated carbon.

Milk Plant Wastes.—The report of Barritt (18) contains an account of the application of the activated sludge process to milk plant waste, diluted to a maximum of 500 p.p.m. B.O.D. Effluent B.O.D.'s of 10 p.p.m. are readily maintained. Eldridge (55) describes further experiments on treatment of cheese plant waste by the Guggenheim process. Average B.O.D. removal was 88.5 per cent, using 280 p.p.m. lime, 56 p.p.m. ferric chloride, and a 4.5 hour aeration period. Hepburn (91) reviewed milk waste treatment in Victoria, Australia, and stated that fair results are obtained by coagulation with aluminum salts. Beijer (20) prevented decomposition of milk wastes by the addition of tanning substances, such as chrome-alum.

Scarlett (211) described a plant for milk waste treatment in which the wastes are subjected to a one-day aerobic fermentation at 30° C., sedimentation, straining through cocoanut fibre mats, and treatment on

trickling filters. Sludge is dumped on land. B.O.D.'s of 400 to 800 p.p.m. in the raw waste are reduced to 10 p.p.m. in the effluent.

Oil Refining Waste.—Hill (101) has described a commercial separator of unusual design for separating oil from refinery drainage, in which emulsions are broken by preliminary passage of the waste through a bed of crushed rock. "Milk-water," the oil-in-water emulsion resulting from soda washing of acid-treated oils, is treated by acidifying and coagulating with aluminum or calcium salts. Crude oil tank bottom emulsions are cracked by heating. Acid sludge is treated to recover sulfuric acid, either by cooking with steam and a fluxing oil, separating oil and acid liquor, using the oil for fuel and concentrating the acid in vacuum evaporators, or by coking the sludge and converting the sulfur dioxide evolved to acid. Sulfonic acids may also be recovered. Soda sludges may be acidified and steamed to remove hydrogen sulfide and mercaptans, which are burned in a furnace; the residual liquor is discharged with the other refinery effluents. Lead sludges are re-activated by soda and air-blowing.

Packinghouse Waste.—Knechtges, Dawson and Nichols (131) have performed comparative experiments on continuous digestion of domestic sewage sludge, sludge from packinghouse waste, and mixtures of the two. Packinghouse sludge digested better when mixed with domestic sludge than when incubated alone; for example, a mixture of 1 part domestic sludge and 2 parts packinghouse sludge on a solids basis required 25 per cent less digestion tank capacity than would be required if the two were digested separately. The maximum additions of solids that were completely digested were 4.02 lb. pr cu. ft. of digester per month for domestic sludge, 2.62 lb. for packinghouse sludge, and 3.86 lb. for the 1 to 2 mixture. Determinations of the lipid material in the sludges indicated that some lipids escape digestion. In no case was it necessary to control the pH, which remained at 6.8 to 7.2.

Pickling Waste.—Hodge (102) has published a complete resumé of the methods used for disposal and treatment of sulfuric acid—iron pickling liquors. In the Dorr process the liquors are neutralized with ground limestone, in conjunction with air agitation and recirculation of sludge. New variations in copperas recovery processes includes the Butler-Little process in which the pickle liquor is sprayed in a lead-lined tower, and crystallization takes place in a conical tank at the bottom of the tower. The Gaver process, by electrolysis with alternate iron and zinc electrodes, followed by zinc and lead electrodes, produces electrolytic iron and sulfuric acid. Various processes are described for combining ammonia liquors with pickling liquors to produce ammonium sulfate and iron compounds. Ferric phosphate is produced by neutralizing the liquor with phosphate rock. Other processes too numerous to cover in this report are also described. Inadequate markets for the products have retarded the development of most of them.

According to McNicholas (146) at Walsall, England, mixed acid wastes, including pickling, lead-tube drawing (lead and nitric acid),

chromium plating, and nickel plating wastes, are neutralized with milk of lime in baffled brick mixing channels, before admission to main sewers.

Plating Wastes.—From a study of the survival of *B. Aerogenes* in chromium plating wastes, Monk (161) concluded that 50 p.p.m. of chromates (as CrO_3) might be permitted in sewage without injury to a treatment plant. The chromium compounds tend to concentrate in the sludge. In chromium plating, the chief waste is "swill" or wash water, containing 130 p.p.m. chromate as CrO_3. In the chromic acid process of anodizing, "swill" water and, occasionally, the acid vat liquors, containing 46,000 p.p.m. of chromate as CrO_3, are discharged.

Spencer (229) described a trickling filter plant in which biological action was stopped by chromates, the concentrations ranging from 3.5 to 67.6 p.p.m. as Cr; the source of the chromate was alkaline wash water containing 764 p.p.m. Cr. The difficulty was solved by treatment of the waste, prior to discharge, by the addition of barium chloride, at pH 7.5. The precipitation is done in lead-lined tanks, in which the barium chloride and sodium carbonate are mixed with the waste by compressed air agitation. The mixture is settled for one hour, and additional sodium carbonate is put in to precipitate the excess barium. After a second agitation, the waste is allowed to settle overnight, and then decanted from the precipitate to the sewer over a period of 4 to 6 hours. The chromium was reduced to 10 p.p.m. by an excess of 150 to 400 p.p.m. of barium (as Ba).

Metals and ammonia may be recovered from plating and other wastes by the use of base-exchange materials, such as hydrogen zeolite, according to British patent 492,344, issued to the I. G. Farbenindustrie.

Pulp and Paper Waste.—The subject of pulp and paper mill waste has been reviewed by Skinner (223) who describes several recent developments in recovery of sulfite waste and white waters. Hill's (100) experiments on the digestion of mixtures of paper pulp and domestic sewage sludge showed that good digestion was obtained at ratios of volatile pulp solids to volatile sludge solids as high as 2.13 to 1. The volatile solids of paper pulp either digested more rapidly or yielded more gas than the volatile solids of the sludge. The average rate of addition was 1.34 lb. of total solids per month per cu. ft. of tank capacity.

Skewes and Benson (222) have investigated the production of oxalic acid from sulfite pulp cooker liquor. The best yields of acid were obtained by the action of concentrated nitric acid on either the evaporated liquor, the precipitated calcium ligno-sulfonate (from lime treatment of the liquor) or the dry solids of the liquor. No acid was obtained from the unconcentrated liquor.

Hawley (90) described the use of a cylindrical-screen save-all for recovery of fibre from white-water. Recovered fibre and part of the screened white-water are returned to process.

Tannery Waste.—Treatment of tannery waste by fill-and-draw sedimentation, with equalization of tan liquors, according to Eldridge

(55) gives removal of 95.5 per cent of the suspended solids, and 62.2 per cent of the B.O.D. Sludge, amounting to one-third of the total waste volume, is dried with some difficulty on sand beds. Some European tannery waste treatment plants, including one in which the settled waste is treated on trickling filters, and the sludge digested, have been described by Masner (151). The author minimizes the danger of anthrax infection from the waste, and states that disinfection by chlorine requires large dosages.

Textile Wastes.—An extensive study of chemical precipitation of textile wastes was made by Porges, Horton and Baity (182). *Sulfur dye waste*, having a B.O.D. of 20,000 p.p.m., was successfully coagulated by strong acids, alum, copper, sulfate, iron salts plus acids, and iron salts alone. The tendency of the acidic compounds to produce hydrogen sulfide and after-precipitation of sulfur led to the conclusion that copperas alone (214 lb. per 1,000 gal.) was most satisfactory. Sludge volumes were very high (80 per cent or more) but the sludge filtered well. Flocculation was of no value, but addition of coal dust or sand and heating of the waste gave better color removal, more rapid settling, lower sludge volumes (around 40 per cent) and better filtering rates. With *kier waste*, the best results were obtained from alum or alum plus acid, with color reduction from 5,000 p.p.m. down to 100 or 200. Copperas and lime were most economical, reducing color to 300 p.p.m. Carbon dioxide and calcium chloride (Copson process) reduced color only to 600 p.p.m. For *indigo waste, vat dye waste and wash waters, direct dye waste, and developed color waste*, lime and copperas or, in some cases, other iron salts, proved satisfactory. *Naphthol color waste* was best treated with sulfuric acid, and *aniline black wash water* with alum and lime.

Composite mill waste, consisting of wastes from indigo and sulfur dyeing, was coagulated with lime (20 to 50 lb. per 1,000 gallons) and *lagoon waste* from the dye pond, with lime, copperas and lime, and alum and lime. Mixtures of mill waste and domestic sewage allowed a wide choice of coagulants.

It was noted that each coagulant appeared to have a definite optimum pH zone, regardless of the type of waste treated, and that titration curves were of value in determining this optimum zone. In general, the conclusion was that satisfactory color removals, and B.O.D. reductions of 80 to 85 per cent were attainable.

In the discussion of the foregoing paper, Nichols (169) described the treatment of wastes from a mill which bleaches, dyes, prints, and finishes cotton cloth. The dye wastes are equalized, treated with 3.8 lb. of alum and 2.5 lb. of lime, mixed, settled, chlorinated, mixed with the bleach wastes, and discharged into the stream through a pipe which distributes them across the entire width. The sludge, and also the strong kier wastes and first rinses, are discharged to gravel pits remote from the stream.

Hoover (104) in a general discussion of the textile waste problem, showed that of the combustible matter in dye wastes, 25 per cent was

suspended, 45 per cent colloidal, and 30 per cent in true solution. Recovery of 50 per cent of the caustic soda in kier wastes was effected by dialysis, rendering the residual liquor easier to treat. Coagulation studies led to selection of ferric and ferrous sulfates as the best general coagulants. B.O.D. determinations on textile wastes were rejected in favor of chromic acid wet-combustion, on account of the difficulties experienced. Tests on straining filters of coke breeze, bituminous coal, and coal ash on both composite and individual wastes proved the coke and coal beds to be superior to ash beds in purifying capacity, and in ease of disposal, since they can be burned under boilers after use. The fibre and hair in mixtures of domestic sewage, woolen and hat factory wastes were destroyed by thermophilic digestion of sludge at 55° C. Two plants treating composite textile wastes were described, one using copperas and lime, the other ferric sulfate and lime, at chemical costs of 3 to 5 cents per thousand gallons, and total costs of 9 to 13 cents per thousand gallons. Sludges in these plants are dried in sand-bottomed lagoons.

Weston's (256) general review of textile waste treatment contains data of great value. The plant at Albermarle, N. C., described by Moore (163) treats mixture of textile wastes and domestic sewage, on trickling filters, the effluent from which may be treated with lime and alum, followed by flocculation and sedimentation.

Miscellaneous.—Waste from the manufacture of synthetic rubber may be treated on land, if diluted with an equal volume of domestic sewage, or on trickling filters if diluted in a ratio of 1 to 1.5, according to Arakantsev (15). A British patent (493,716) issued to the I. G. Farbenindustrie, describes the recovery of ammonia from cuprammonium rayon wastes by passing the warm wastes through a countercurrent of steam, recovering the condensate. British patent 498,799, issued to the Vereinigte Glanzstoff Fabriken, describes recovery of carbon disulfide from viscose rayon wastes by aeration under vacuum.

Effect of Industrial Wastes on Sewage Treatment

A comprehensive review of the effects of a number of industrial wastes on sewage treatment processes is given by Eldridge (51). The review includes beet sugar, milk, pickling, cannery, meat packing, tannery, textile, laundry and paper wastes. Similar reviews have been published by Hurley (109) and Dupont (49).

Sedimentation.—The effects of paper mill waste on a plain-sedimentation separate sludge digestion plant are described by Kronbach (136). They include clogging of clarifiers by the rapidly concentrating sludge, blocking of pumps, formation of heavy fibrous mats on the top of the digesters, and interference with the drawing of supernatant liquor.

Sludge Digestion.—According to Koon (133) the sewage plant at Yakima, Wash., handles cannery wastes which contribute twice the solids load contributed by the domestic sewage. No operating difficulties have been experienced.

Trickling Filters.—The inhibition of biological action on a trickling filter by chromium plating wastes is described by Spencer (229) (see *Plating Wastes*). Overloading of the trickling filters at Austin, Minn., by packinghouse wastes discharged to the city sewers led to the construction of preliminary high-rate filters and intermediate sedimentation tanks ahead of the original filters. Facilities for chemical precipitation were added to the primary sedimentation tank. The design and construction of the plant, and the results expected are described by Hansen and Hill (83). Treatment of the packinghouse waste by the chlorine precipitation process proved to be insufficient under the local conditions.

Activated Sludge.—Porges and Miles (183) in an experimental study of the dewatering of activated sludge containing sulfur dye waste, showed that the presence of the waste approximately doubled the coagulant demand of the sludge. The waste-containing sludge was produced by aerating activated sludge with sewage containing 1 per cent dye waste.

Stream Pollution

Prospects for increased Federal funds for research in stream pollution and a national program of pollution control improved with the submission to Congress on February 16th of a message from the President outlining such a program. Accompanying this message was a Committee Report (1) by the Advisory Committee on Water Pollution of the National Resources Committee. It was estimated in this report that public and private expenditures totalling $2,000,000,000 would be required over a period of 10 to 20 years to abate the more objectionable pollution. The report recommended Federal legislation which was subsequently passed by the Senate in the form of a revised Barkley-Vinson Bill called the Barkley Bill (S-685). A similar measure has been introduced in the House and is awaiting House action at the second session of the 76th Congress. That a program of this nature could be justified on the basis of monetary savings was indicated by a study of losses due to pollution in New York harbor and adjacent waters by Hess (93) who estimated the direct losses due to pollution in this area had been $127,000,000 over a period of 20 years or a sum sufficient to have built sewage treatment works to abate all of the pollution which caused these losses. Indirect losses would undoubtedly have increased his estimate considerably had it been possible to determine them accurately.

Continuing outbreaks of gastro-enteritis have resulted in increasing attention being given to the quality of both raw and purified water. In a symposium on water quality, Levine, Carpenter and Coblentz (140) reported on the characteristics of 282 strains of organisms isolated from 97 well chlorinated water samples from 5 cities. Of these, 196 were strains of the coli-aerogenes group (63.8 per cent of these being slow lactose fermenters at 37° C.), 5 belonged to the genus Salmonella, 4 to the genus Shigella and 8 to the genus Eberthella, the lat-

ter three being from groups associated with gastro-enteritis, which leads the authors to conclude that present chlorine residuals of .2 to .4 p.p.m. as determined by ortho-tolidine do not necessarily indicate adequate water sterilization. Streeter (236) pointed out that lowering the average coliform limit of purified water from 1 to .2 per 100 cc. would probably necessitate control of water pollution to bring the corresponding average raw water maximum from 5,000 to 200 per 100 c.c. and that general attainment of zero coli effluents was virtually impracticable.

Water-borne outbreaks in the United States and Canada during the years 1920–36 inclusive have been summarized by Gorman and Wolman (71), who found that 63 of the 399 outbreaks in the United States, involving 21 per cent of the typhoid cases and 52.8 per cent of the persons affected, were due to improper operation of water treatment plants or unsatisfactory chlorination. Although increased vigilance of those responsible for water purification processes is clearly indicated, the provision of a factor of safety by reducing raw water pollution is also indicated in many instances.

Young (265) discusses the effects of low flow augmentation from Pymantuning Reservoir on the Beaver River. Minimum flows have been increased from 23 c.f.s. (6 weeks period) to 123 c.f.s. and will probably be maintained above 200 c.f.s. River conditions during the first year did not greatly improve because there was increased industrial activity on the river during this period and a poor quality of water had been impounded in Pymantuning Reservoir due to the swampy nature of the reservoir site. However, completion of the accompanying program of treatment for sewage and industrial wastes and improvement in the quality of impounded water should alleviate present difficulties.

The bacteriological quality of natural waters required for recreational purposes, particularly in bathing and swimming areas, has been a highly debatable point. Chlorination of sewage treatment plant effluents which might affect natural waters is frequently expensive and not entirely satisfactory. An economical answer to this problem, in part, may be the provision of closed beach areas such as was constructed at Springfield, Illinois, and reported by Bonn (24). As part of an extensive recreational development of the impounded source of Springfield's water supply, a section of beach waterfront was enclosed with sheet piling, water was pumped from the lake, chlorinated and allowed to flow back to the lake through 3 inch holes in the sheeting. Residual chlorine of .1 to .2 p.p.m. was maintained in the effluent water from the pool.

Geiger, Hyde and Crowley (68) report the favorable effect of wide publicity being given to the polluted condition of bathing beaches in the San Francisco Bay area. Following an extensive bacteriological survey, a definite quarantine was placed against bathing in waters that were polluted, among which were several of the popular bathing beaches. Public demand necessitated calling a special election at which

sewer bonds (usually defeated) for the correction of the pollution were passed by an unusually heavy favorable vote.

Fair (60) presents an interesting analysis of Streeter and Phelp's "oxygen sag" formulation. Diagrams are given for the graphical solution of this formulation to determine maximum stream loading, the coordinates (time and saturation deficiency) of the point of minimum dissolved oxygen and the coordinates of the point where the maximum rate of recovery occurs, using various assumed values for the coefficients of deoxygenation and reaeration. The expressions which Fair derives are simplified somewhat by use of a "self-purification constant" (f) which is the ratio

$$\frac{\text{reaeration constant } k_2}{\text{deoxygenation constant } k_1}.$$

The author, on the basis of "present information" defines approximate limits for the value of (f) from that given for small ponds and backwaters, .5 to 1.0, to above 5.0 for rapids and waterfalls.

Sludge bank formation in a small impounding reservoir receiving the effluent from a trickling filter plant was studied by Ridenour and Henderson (190). They found that only 17 per cent of the sludge volume present after 8 years could be ascribed to accumulation from suspended solids (32 p.p.m.) in the plant effluent while 83 per cent were due to silt and decaying vegetation. Average flow into the reservoir was 8 c.f.s. of which 1.46 c.f.s. was sewage effluent. The total volume of sludge produced (60 per cent moisture) was slightly less than that which would have been produced (90 per cent moisture) in a digestion tank. Decomposition of sludge was uniformly slow over the entire lake except within 200 feet of the outfall where it was much more rapid. As indicated by the high ratios of nitrogen per gram of volatile matter compared to the ratios of B.O.D. per gram of volatile matter in the older sludges, the nitrogenous fractions were in general stabilized much more slowly than the carbonaceous fractions. Reduction of B.O.D. in the sludge was 90 per cent on a volatile matter basis. Considering the lake as a sewage treatment process, the reduction in suspended solids was 95 per cent, and in B.O.D. 66.5 per cent in winter and 52.5 per cent in summer, at a loading of 190,000 gallons of trickling filter effluent per acre per day. No nuisance had occurred in the lake although oxygen contents as low as 0.5 p.p.m. had been observed during a critical summer period. Giesecke (69) also reports satisfactory results in the operation of a lake disposal system at Kingsville, Texas. Although dissolved oxygen is generally depleted at depths below 7 feet, the lake has operated successfully for four years.

Biologic Life.—In investigating the cause of mass destruction of fish on the Schuylkill River, Schaut (212) studied the effects of certain industrial wastes and certain naturally occurring organic compounds upon minnows in aquaria. The most active of these compounds was rotenone which was toxic to fish in a concentration of .03 p.p.m. So-

dium cyanide was toxic in a concentration of .75 p.p.m. and during the drought period when mass fish killings occurred, concentrations of 1 to 5 p.p.m. were measured in a pool where fish were killed. It was estimated that 2 tons of cyanide were present in the pool, an amount which could not have been contributed by industries above. Tests of the river water above and below this pool were negative for cyanides. Oxygen deficiency, chlorides or nitrites could not have caused the fish destruction and the author suspects the production of cyanides by hydrolysis of a naturally occurring cyanogenetic compound, one of which, amygdalin, he demonstrated was hydrolyzed by the river water and could be hydrolyzed enzymically in the presence of minnows in an aquarium.

Hardy (85) reported that many young fish live in the highly polluted Mersey estuary but do not spawn there. Summer spawning varieties of salmon have disappeared but spring spawning varieties have not. The shellfish industry was affected to a greater degree than other fisheries and the delicate organisms such as sea anemones, nudibranchs and sponges have been destroyed.

Reporting on investigations in progress at Gray's Harbor, Washington, Townsend, Eriksen and Earnest (243) found that although vast quantities of unpolluted ocean water entered and left the bay through tidal action, the polluted fresh water maintained its identity throughout the tidal cycle but was displaced laterally a distance of several miles. Polluted conditions were not alleviated until river discharges increased. Anadromous fish apparently did not penetrate this pollutional barrier to spawn at the usual time but many were found in a distressed condition or dead in the polluted areas of the bay. Tending to bear out the observations of Hardy (85) regarding the absence of delicate sea organisms, the authors noted the complete absence of starfish, sea urchins and jellyfish in Gray's Harbor. The tolerance limit of certain fish to low oxygen concentrations was investigated by keeping the fish in laboratory tanks for a period of 18 to 25 hours at temperatures of 10° to 13° C. with the following results: Silver salmon fingerlings 1.25 p.p.m., yearling steelhead trout 1.50 p.p.m., 110 to 165 mm. long cutthroat trout 1.40 p.p.m. Usually a decrease of 0.1 p.p.m. below the limits given produced symptoms of distress within 30 minutes.

Surveys.—In a report of studies of the pollution of the Raritan River, Rudolfs (199) described the condition of the river during 1937–38, comparing the results of a year's observations with those of a similar survey made in 1927–28. Several sewage treatment plants had been placed in operation in the interim between the two surveys and others were under construction. Bacterial pollution as indicated by total counts had decreased slightly and coliform bacteria showed a very material reduction. In the later survey both total counts and coliform organisms were lower in summer than in winter, the reverse of the situation 10 years previous. In contrast with the improved

bacteriological condition of the river, chemical analyses indicated increased pollution due to industrial wastes.

Weston and Edwards (257) studying the pollution of Boston Harbor in 1935–36 found no serious oxygen depletion in the harbor but the presence of areas of sleek, floating grease and solids created a nuisance in many places, and such floating material was likely to be carried back from distant outfalls to the beaches. Pollution of beaches was largely due to local sewer outlets and storm water overflows which discharged directly into the harbor. The report recommended preliminary treatment of the sewage in sedimentation tanks equipped with skimming and sludge removal devices.

Williamson and Greenbank (260) studied the pollution of Fox River and Green Bay in Wisconsin to determine the cause of fish deaths in commercial fishermen's nets. Although no fish mortality was observed or reported in Green Bay during the period of the survey, the winter of 1938–39, dissolved oxygen concentrations as low as 2.6 p.p.m. were measured, even though there was about 30 days less ice coverage than during a normal winter. Construction of sewage treatment plants has removed unsightly scum and sludge banks from the lower river and reduced health hazards by cutting down the bacterial load, but has not eliminated oxygen deficiency troubles because only 7 per cent of the total oxygen demanding materials were supplied by sewage, 88 per cent being from waste sulfite liquor and 5 per cent from "white water" and other sources. Summer odor nuisances in the East River were due partly to pollution in that river but largely to frequent reversals of flow in the lower stretches which carried waste sulfite liquor upstream. Carbohydrates contributed the major portion of oxygen demand of the waste sulfite liquor, the lignin a variable amount depending on the absence or presence of carbohydrates, while free sulfur dioxide contributed a negligible amount. Treatment of waste sulfite liquor by lime precipitation removed largely sulfur dioxide and lignin, effecting only 31 to 45 per cent B.O.D. removal, which would be insufficient removal to make conditions satisfactory in Green Bay. Further study of the problem was advocated, particularly of the possibility of treating waste sulfite liquor along with sewage on biological filters.

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ACTIVATED SLUDGE OXIDATIONS

VI. RESULTS OF FEEDING EXPERIMENTS TO DETERMINE THE EFFECT OF THE VARIABLES TEMPERATURE AND SLUDGE CONCENTRATION

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One of the most debated points in connection with the activated sludge method of sewage treatment is the question: What concentration of activated sludge should be maintained for a given operating condition? The consensus at present seems to be that mechanical aeration devices are best suited to concentrations of from 600 to 1,000 p.p.m. of activated sludge and diffused air plants to concentration ranges from 1,000 to 4,000 p.p.m. Attempts to correlate the concentrations of activated sludge used with B.O.D. loadings appear to be fruitless. It is known, however, that the characteristics of the sludges produced with high and low concentrations are often quite different. In the hope that some light might be shed on the issue, the investigations reported in this paper were started.

In a previous publication, Sawyer and Rohlich (1) have shown that at some treatment plants the nitrifying ability of the activated sludge varies markedly with the season of the year. Low winter temperatures apparently are conducive to the development of non-nitrifying sludges and summer conditions to the development of nitrifying sludges. In order to confirm or disprove this contention, simultaneous laboratory feeding experiments were conducted under conditions which eliminated all other variables except temperature.

Methods

Studies at 10, 15, 20, and 25 Degrees C.

Identical portions of an activated sludge obtained from the Madison, Wisconsin, plant were placed in wide mouthed bottles of two-gallon capacity. The amount of sludge was so chosen as to give an activated sludge concentration of 1,000 p.p.m. when each bottle was filled to capacity with sewage. The bottles were placed in constant temperature-baths, as shown in Fig. 1, at temperatures ranging from 10 to 25 deg. C. Aeration was accomplished with diffused air sufficient in quantity to keep the sludge in suspension during the aeration period of approximately 10 hours.

The volume of the aeration mixture used in each case was 7½ liters. In preparation for feeding, aeration was discontinued and the sludges allowed to settle for approximately one hour. The supernatant liquor was siphoned off until only 2 liters of supernatant and sludge were

left. The effluent was replaced in each bottle with 5½ liters of fine-screened sewage. The aeration mixture always contained 26.6 per cent of return sludge. The sludges were fed identical portions of Madison sewage twice each day, except Sundays when the sludges were

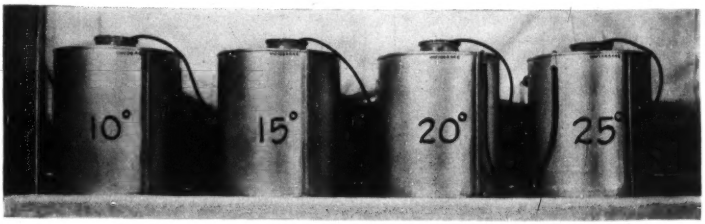


FIG. 1.—Apparatus used in studies at different temperatures.

fed only once. At intervals of two or three days, the suspended solids of the aeration mixtures were determined and enough mixed liquor wasted to reduce the solids to 1,000 p.p.m. Observations were made on rate of growth, B.O.D. removal, oxygen utilization, and extent of nitrification over a 22 day period. Portions of the activated sludges obtained at the end of the feeding experiment were analyzed for their volatile solids and nitrogen content.

Studies with Various Concentrations of Activated Sludge

A. Room Temperature.—Portions of the same supply of activated sludge used for the temperature studies were so chosen as to give concentrations of activated sludge corresponding to 800, 1,600, 2,400, and 3,200 p.p.m. when placed in bottles of two-gallon capacity and filled with sewage. The aeration bottles were kept at room temperature, which approximated 20° C. The sludges were fed concurrently with those at different temperatures, as described above, and treated the same except that the concentration of sludge in each case was always adjusted to the starting value of 800, 1,600, 2,400 or 3,200 p.p.m. The feeding of these sludges was conducted for a period of 52 days.

B. At 10° C.—This experiment was similar to the one conducted at room temperature in all details except temperature and duration of the experiment, which continued for only 34 days.

Sewage for all the feeding experiments was obtained from the main pumping station in the city of Madison to which all sewage of the metropolitan area flowed and was essentially a representative domestic sewage containing about 10 per cent of a chemically treated packing-house waste (animal). The 5-day B.O.D. of the sewage fed varied from 154 to 382 p.p.m. and averaged 248 p.p.m.

Routine chemical analyses were performed according to methods outlined in *Standard Methods of Water Analysis 1936*, except that the digestion of the activated sludges in the determination of their nitrogen

content was accomplished with the use of copper selenite as a catalyst. The preparation of copper selenite has been described by Hurd, Kemmerer, and Meloche (2), and the advantages of copper selenite as a catalyst have been described by Schwoegler, Babler, and Hurd (3). Determinations of oxygen utilization by the activated sludges were made with the aid of the Oxy-Utilometer (4).

Experimental Results

Studies at 10, 15, 20, and 25° C.—1,000 P.P.M. Activated Sludge

One of the first differences exhibited among the sludges fed at different temperatures was the impaired clarification produced by the sludge maintained at 10° C. This resulted in somewhat poorer B.O.D. removal, as is shown by the data given in Table I. The apparent improvement in B.O.D. removal shown by the sludge fed at 10° C. on the 18th day was found to be temporary. Because of the interesting changes this sludge appeared to be undergoing, its feeding was continued after the 22nd day of the experiment. The B.O.D. of the effluents produced by this sludge on the 37th and 45th day were found to be 35.4 and 26.2 p.p.m., respectively.

Table I.—*B.O.D. of Effluents Produced by Activated Sludges Fed on Identical Diets at Different Temperatures*

Parts per Million

Temperature Centigrade	7th Day	13th Day	18th Day	Avg. Per Ct. B.O.D. Removal
10°	28.0	23.7	16.4	90.5
15°	10.0	15.4	15.5	94.3
20°	10.5	16.8	12.0	94.5
25°	14.0	13.9	11.0	94.6

Determinations of the extent of nitrification were started on the seventh day of the feeding experiment and continued at intervals thereafter. The data are shown in Table II, from which it can be seen that the extent of nitrate formation at 10° C. was somewhat curtailed by the 7th day and gradually became less and less until it had practically disappeared on the 22nd day.

Table II.—*Nitrate Production by Activated Sludges Fed on Identical Diets at Different Temperatures*

Parts per Million as N

Temperature Centigrade	7th Day	13th Day	14th Day	22nd Day	36th Day
10°	12	4	4	2.8	0.0
15°	16	16	20	22	—
20°	20	16	24	22	—
25°	22	18	24	22	—

The experiment with the sludge maintained at 10° C. was continued for 59 days, but after 31 days the effluent contained no nitrates. The formation of nitrites was found to continue somewhat longer as can be seen from Table III, but by the 36th day the nitrite nitrogen had reached a minimum value of about 2.5 p.p.m., below which the value did not fall appreciably. With the disappearance of the ability to oxi-

TABLE III.—*Nitrite Production by Activated Sludges Fed on Identical Diets at Different Temperatures*

Parts per Million as N

Temperature Centigrade	7th Day	14th Day	22nd Day	36th Day	59th Day
10°	—	18.0	25.0	2.5	2.0
15°	—	0.4	0.5	—	—
20°	—	0.1	0.4	—	—
25°	—	0.1	0.0	—	—

dize ammonia nitrogen, the concentration of ammonia nitrogen in the effluent gradually increased. On the 46th day when both nitrite and nitrate formation were at a minimum the effluent from the portion of sludge fed at 10° C. contained 18.4 p.p.m. of nitrogen as ammonia.

A record of the amount of activated sludge wasted in order to keep the solids in each of the aeration bottles near 1,000 p.p.m. was made over a three weeks period of the feeding experiment. It was found that the rate of growth was influenced markedly by temperature and that the most rapid growth occurred at 15° C. The rate was slowest at 25° C. The relative data are presented in Fig. 2 and show that the amount of activated sludge to be wasted under winter conditions is

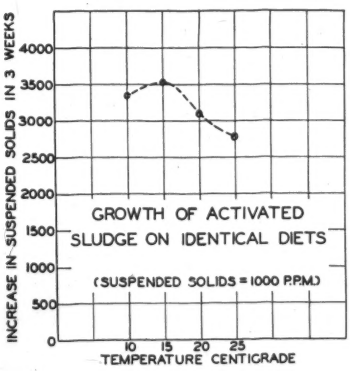


FIG. 2.

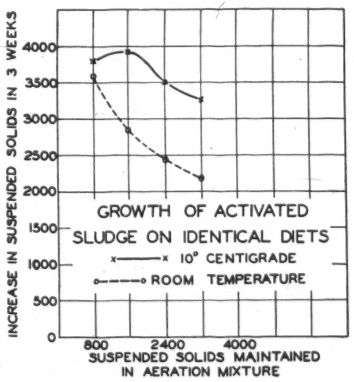
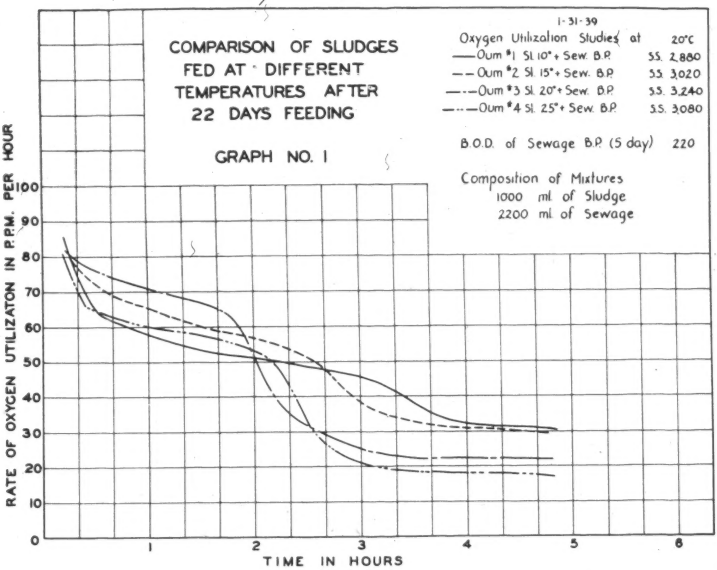


FIG. 3.

somewhat greater than under summer conditions, provided all other variables are constant.

After feeding the sludges at the different temperatures for 22 days the oxygen utilization characteristics of all were compared at one temperature, namely 20° C. The sludges were adjusted to 20° C. and fed identical portions of sewage at the same temperature when the comparison was made. The results are given in Graph 1 from which it



can be seen, as shown by the author in a previous publication (5), that the nitrification phase was completed in about 2½ hours with the sludges which had been fed at 20 and 25 deg. C., while in the case of the sludges fed at 10 and 15 deg. C. about 3½ to 4 hours were required. This difference is thought to have been due to a decreased population of nitrifying organisms in the latter sludges and to have been correlated with the loss of nitrate forming power by the sludge fed at 10° C. After the fourth hour of aeration, the oxidation was undoubtedly concerned with the stabilization of the remaining carbonaceous material, and it was found that the sludges, when compared at the same temperature, showed rates of oxidation which might have been predicted from the various temperatures at which the sludges had been fed for the previous 22 days, according to the findings of Sawyer and Rohlich (1) on summer and winter sludges: namely, the sludge which had been fed at 10° had the highest rate, and the sludge

fed at 25° had the lowest rate with the other two falling in their proper order.

Studies with Various Concentrations of Activated Sludge

A. Room Temperature.—Activated sludge concentrations of 800, 1,600, 2,400, and 3,200 p.p.m. were used in this study. For purposes of convenience the different sludges have been designated as R°–8, R°–16, R°–24, and R°–32.

During the first week of the feeding experiment, the effluents produced by the sludges R°–8 and R°–16 were much superior in appearance to those given by the higher solids concentrations. Thereafter the quality of the effluents produced was quite comparable, as will be seen from the data in Table IV.

TABLE IV.—*B.O.D. of Effluents Produced by Activated Sludges of Different Concentrations Fed on Identical Diets at Room Temperature*

Parts per Million

Sludge	Sludge, P.p.m.	7th Day	13th Day	18th Day	40th Day	48th Day
R°– 8	800	6.5	24.5	11.5	7.0	5.5
R°–16	1600	8.0	24.5	12.3	—	—
R°–20	2000*	—	—	—	8.0	5.5
R°–24	2400	13.5	24.0	14.1	—	—
R°–32	3200	16.5	20.0	13.1	9.0	3.5

* After 30th day sludges R°–16 and R°–24 were combined to form R°–20.

Investigations of nitrate production by the various sludge mixtures fed at room temperatures were made periodically and the data are shown in Table V. From this table it can be seen that the nitrifying

TABLE V.—*Nitrate Production by Activated Sludges of Different Concentrations Fed on Identical Diets at Room Temperature*

Parts per Million Nitrate Nitrogen

Sludge	Sludge, P.p.m.	7th Day	15th Day	23rd Day	41st Day	52nd Day
R°– 8	800	20	20	20	16	16
R°–16	1600	20	20	24	—	—
R°–20	2000*	—	—	—	26	20
R°–24	2400	24	20	24	—	—
R°–32	3200	26	20	24	26	22

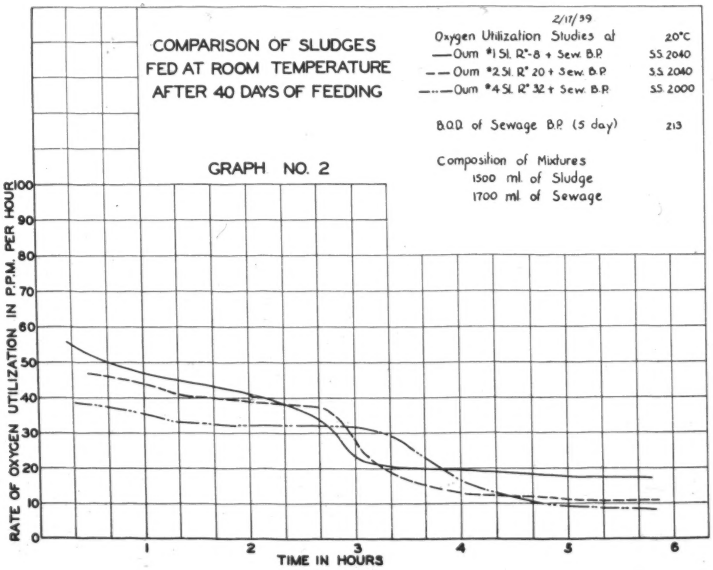
* After 30th day sludges R°–16 and R°–24 were combined to form R°–20.

ability of the original sludge was maintained throughout the period of 52 days with all the sludges. The smaller amounts of nitrate nitrogen in the effluents produced by the lower concentrations of acti-

vated sludge is of significance and can be correlated with rates of growth and nitrogen content of the sludges produced as will be discussed presently. The amount of nitrite-nitrogen in the effluents produced by these sludges was always low, and in no case was there more than a trace (0.4 p.p.m) of ammonia nitrogen found in them.

The rate of growth of these sludges decreased as the concentration of the activated sludge increased in the aeration mixture. Similar results have recently been reported by Ingols and Heukelekian (6) and by Ruchhoft, Butterfield, McNamee, and Wattie (7). The data are given in Fig. 3, and show that the quantity of sludge produced in the lowest suspended solids (800) mixture was approximately 65 per cent greater than in the highest (3,200). The significance of this factor in the design and economy of sludge disposal facilities should not be overlooked.

A comparison of the oxygen utilized by the various sludges was made on the 23rd and the 40th days of the experiment. The differences were distinct on the 23rd day but not as definite as they had become on the 40th day. For that reason, the results obtained on the



40th day are given in Graph 2 and show that when equal quantities of each sludge were used the oxygen requirement of sludge R°–8 was greatest and that of sludge R°–32 was the least. This was to be expected on the basis that sludge R°–8 had been relatively overfed when

compared to the sludges with the higher sludge concentrations, and it is further evidence to support the belief that the activity of a sludge is a function of the food load it has been accustomed to stabilizing.

B. 10° C.—The suspended solids concentrations used in this study were the same as in the one just described and for differentiation are designated as 10°–8, 10°–16, 10°–24, and 10°–32.

From the start of the experiment, the effluent produced by the lowest suspended solids concentration (800) was quite turbid and had a rather high B.O.D., as is shown by the data in Table VI. The B.O.D.

TABLE VI.—*B.O.D. of Effluents Produced by Activated Sludges of Different Concentrations Fed on Identical Diets at 10° C.*

Parts per Million

Sludge	Sludge, P.p.m.	5th Day	13th Day	21st Day	28th Day	Avg. Per Ct. B.O.D. Removal
10°– 8	800	48.0	36.0	24.5	30.0	84.0
10°–16	1600	11.5	12.0	6.7	5.7	95.9
10°–24	2400	5.0	6.7	6.8	6.1	97.2
10°–32	3200	8.0	6.6	5.5	7.6	96.8

of the effluents produced by the other sludge concentrations at the same temperature was low in all cases and indicated that they were capable of handling the food load imposed on them without any difficulty.

A study of nitrate formation by these sludges showed that the loss of nitrifying ability was not uniform but varied with the concentration of sludge used, as may be seen from inspection of Table VII. This

TABLE VII.—*Nitrate Production by Activated Sludges of Different Concentrations Fed on Identical Diets at 10° C.*

Parts per Million Nitrate Nitrogen

Sludge	Sludge, P.p.m.	6th Day	11th Day	28th Day	32nd Day	34th Day
10°– 8	800	8	4	0.6	0.0	0.0
10°–16	1600	12	8	9.0	8.0	6.0
10°–24	2400	20	16	14	22	28
10°–32	3200	24	24	16	20	28

indicates that other factors besides temperature are important in determining whether or not nitrifying ability persists at low temperatures.

The greatest objection to nitrifying sludges, no doubt, is the requirement of increased amounts of oxygen, and the second objection of major importance is probably the characteristic which such sludges possess of floating to the surface if kept in the absence of dissolved oxygen for any great periods of time. This latter difficulty was en-

countered in connection with some of the sludges used in the studies at 10° C. Photographs were made to record some of the observations and a representative group are shown in Fig. 4. View "a" was taken 30 minutes after the samples of the various sludges had been placed

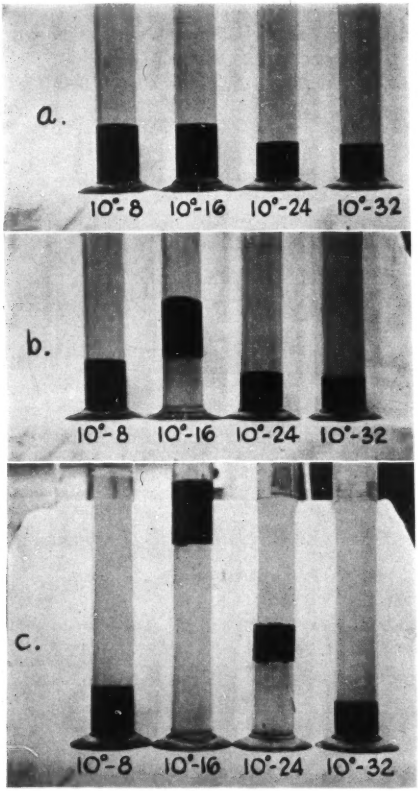
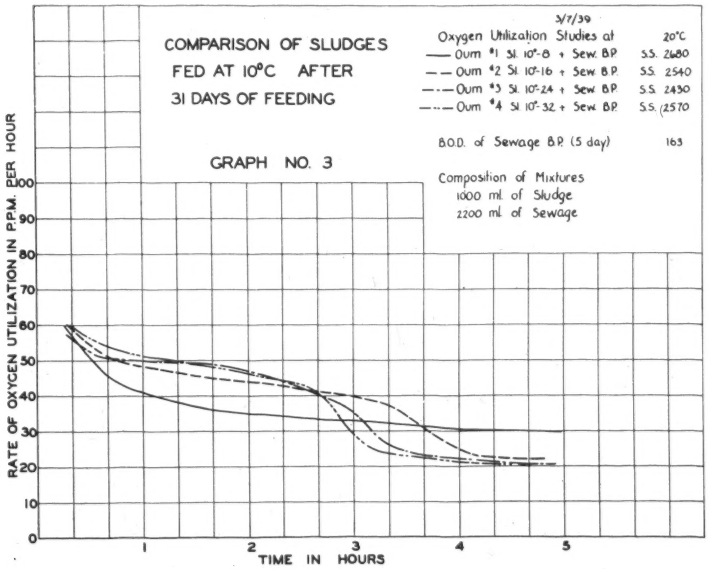


FIG. 4.—Views of settled activated sludge which illustrate the relationship of activated sludge concentration and nitrification to the "rising" characteristic of some sludges. View "a"—after 30 minutes settling. View "b"—after 50 minutes settling. View "c"—after 60 minutes settling.

in the graduated cylinders. View "b" was taken after 50 minutes had elapsed and shows sludge 10°–16 in the process of rising to the surface due to the buoyancy of the gas released and retained within the sludge. View "c" shows the status of affairs after 60 minutes of "settling" in

which we find sludge 10°–24 had started its upward journey and sludge 10°–16 had reached the top. Due to lack of photographic materials a record of the next change was not obtained, but after 70 minutes had elapsed sludge 10°–32 also began to ascend and gradually rose to the surface. Sludge 10°–8 had not risen or begun to show any tendency to do so at 100 minutes when the observations were discontinued. These observations were made on the 27th day of the feeding experiment when nitrite and nitrate formation by sludge 10°–8 had reached a minimum and, consequently, not enough nitrogen gas could be liberated to buoy the sludge. In the other three cases the ability to form nitrites and nitrates was still present and, thus, a sufficient quantity of nitrogen was released in each case. It is of interest to note that of the sludges buoyed up the one which had been relatively over-fed (10°–16) was the first to rise and sludge 10°–32 was the last to rise.

A record of the growth of the sludges fed at 10° C. was also made over a period of three weeks duration. The data are shown in Fig. 3 in conjunction with corresponding data obtained in the studies at room temperature. In the case of the sludges fed at 10° C., the rate of



growth increased with decreasing aeration solids over the range of 1,600 to 3,200 p.p.m., but with the portion of sludge containing only 800 p.p.m. of suspended solids the rate of growth did not follow the trend. The slower growth of this sludge can, no doubt, be attributed

to its failure to remove all of the food material as is shown by the B.O.D. data in Table VI and to its loss of ability to oxidize the ammonia nitrogen in the sewage. The greater amount of new sludge produced by the sludges fed at 10° C. as compared to those fed at room temperature correlates very well with the data shown in Fig. 2.

A comparison of oxygen utilization by the different sludges fed at 10° C. was made after 31 days of feeding. Equal quantities of the sludges were used and the comparisons made at 20° C. The results are shown in Graph 3, from which it can be seen that the oxygen utilization rate curve produced by sludge 10°–8 is typical of a non-nitrifying sludge while those produced by the other sludges are typical of nitrifying sludges (5). This behavior correlates with the nitrate forming ability as shown in Table VII.

Volatile Solids and Nitrogen Content of the Sludges Produced

Because of the importance of the volatile solids content of sludge in determining its value in methane production and the nitrogen content in determining its value as a fertilizer, samples of the sludges obtained at the end of the various runs were dried at 105° C. and analyzed for their content of each. The results are given in Table VIII. From

TABLE VIII.—*Volatile Solids and Nitrogen Content of Activated Sludges Produced with Various Sludge Concentrations and Temperatures*

	Variables											
	Temperature (Centigrade)				Sludge Concentration (Room Temperature)				Sludge Concentration (10° C.)			
	10°	15°	20°	25°	800	1600	2400	3200	800	1600	2400	3200
Volatile Solids....	76.8*	76.6	74.8	73.0	76.3	73.7	72.6	72.5	77.6	77.6	76.9	76.6
Nitrogen....	6.49*	6.61	6.34	5.97	6.49	6.16	5.82	5.77	6.06	6.45	6.48	6.44

* Per cent.

this table it can be seen that the development of sludges with high volatile solids content is favored at low temperatures and low activated sludge concentrations. With respect to the nitrogen content of the sludges, high nitrogen content appears to be favored by low sludge concentrations and by low temperatures, but when the temperature becomes low enough, or the sludge concentration low enough so that nitrification is impaired, the nitrogen content of the resulting sludge is lowered. This is shown especially well by the lower nitrogen content of sludge 10°–800 which had lost its nitrifying ability and some of its clarifying power. It is to be questioned whether the lowered nitrogen content of the sludge is a direct result of the loss of nitrifying ability or a result of over feeding.

Discussion

B.O.D. Removal.—The ability of activated sludge to adapt itself to changing conditions is well shown by the comparable B.O.D. removals given by the various sludge concentrations used in the study at room temperature. In the corresponding study at 10° C., it was found that the B.O.D. removal at the lowest sludge concentration (800 p.p.m.) was much less than at higher concentrations. This is further proof of the contention that temperature is one of the important factors in determining the rate of B.O.D. stabilization, and that higher concentrations of aeration solids are needed under winter conditions than under summer conditions to accomplish a certain amount of work. These data also furnish an explanation of why activated sludge plants using widely different aeration solids concentrations to treat comparable B.O.D. loadings often produce effluents showing equivalent B.O.D. removals.

Nitrification.—The seasonal fluctuation in nitrifying ability of activated sludges which occurs at some treatment plants has been attributed solely to temperature change. The argument is presented that at the low temperatures the nitrifying organisms are under conditions unfavorable for their reproduction. Undoubtedly, this is an important part of the explanation, but, as can be seen from the data on nitrification obtained with the various sludge concentrations at 10° C. (Table VII), the nitrifying ability in the case of the sludge concentrations of 2,400 and 3,200 p.p.m. did not become impaired. There are, probably, at least two reasons for this difference: 1. The dilution factor—because of the more rapid growth in the case of the lower suspended solids concentrations, the rate at which those sludges had to be wasted was greater, and the nitrifying organisms soon became overgrown and outgrown by the other forms of life and their numbers reduced to a minimum value. 2. Available food supply—as a result of the greater growth in the case of the lower suspended solids concentrations, considerably more nitrogen was fixed in the sludge and, consequently, less free ammonia nitrogen was available as a source of energy to stimulate new growth of nitrifying organisms.

Rate of Growth.—The fact that the most rapid growth of the activated sludge occurred at the lower temperatures and with the lower concentrations of activated sludge is somewhat perplexing when viewed from the standpoint of ordinary experiences. In the practice of sewage treatment, there is imposed, however, one restriction which makes its case somewhat singular in character. This is the limited food supply which is made available to the organisms so that complete removal of the food supply (B.O.D.) can be accomplished during the detention period allowed. In the case of the sludges used in this study, all the sludges used in any one particular experiment were fed identical and exactly equal quantities of sewage as food. In those cases where the lowest concentration of activated sludge was capable of utilizing all of the food available, as shown by the B.O.D. removal data,

the sludges of higher concentrations must have been, relatively speaking underfed, and, consequently, more and more of the food available was used for ordinary metabolic needs of the sludge and less and less was available for the production of new growth as the sludge concentration increased.

The greater rate of growth of the sludges at 10 and 15 deg. C., as compared to those at 20 and 25 deg. C. can, undoubtedly, be explained by the greater oxygen requirements of the sludges maintained at the higher temperatures. High oxygen requirements are probably correlated with high metabolic rates, and, as the metabolic rate increases with temperature, the amount of food available for growth diminishes because of the increased amounts of food necessary to maintain the organisms already present.

On the basis of the B.O.D. removal data given in Table I, it would be logical to conclude that the slower rate of growth of the sludge maintained at 10° C., as compared to that of the sludge maintained at 15° C. (Fig. 2), was due to its inability to utilize all the available food material present. This reason is, no doubt, an important one, but it should also be noted that the sludge maintained at 10° C. gradually lost its ability to oxidize ammonia nitrogen to nitrites and nitrates; thus, this source of food energy was not utilized to its full extent and the growth obtained from it was less than at the higher temperatures. Similar arguments can be presented to explain why the rate of growth of the lowest activated sludge concentration (800 p.p.m.) in the studies at 10° C. was less than with 1,600 p.p.m. at the same temperature (Fig. 3).

Volatile Solids Content of Activated Sludges.—The aerobic oxidation of sewage solids or of activated sludge results in a reduction of the volatile solids content as the oxidation progresses. The end result is the development of a sludge with a lower volatile solids content and a much lower requirement for oxygen, similar to the results accomplished by the anaerobic decomposition of such substances. Because of the more rapid rate of oxygen usage by activated sludges at the higher temperatures, sludges maintained at such temperatures on limited food supplies will have lower volatile solids contents than sludges maintained at lower temperatures on identical food supplies. In a like manner, when different amounts of activated sludge are used to stabilize identical amounts of food, the rate of oxidation will be greatest in case of the highest sludge concentration; therefore the volatile solids content will be reduced most rapidly and such sludges will contain less volatile solids. These arguments are substantiated by the data on the volatile solids of the various sludges as shown in Table VIII. On this difference in oxygen requirements can be found an explanation of why mechanical aeration devices are capable of treating sewages with low concentrations of activated sludge, but fail to give satisfactory results when attempts are made to maintain higher concentrations of aeration solids.

The higher volatile solids content of the sludges produced at low temperatures and with low suspended solids concentrations is, undoubtedly, of some importance in the practice of methane production. It is of interest to note that under the conditions most favorable for the greatest growth rates of activated sludge, the highest volatile solids contents are also obtained. This additive property should not be overlooked.

Nitrogen Content of Activated Sludges.—From the data presented in Table VIII, we have seen that the sludges with the highest nitrogen contents are produced, in general, under the same conditions as those with the highest volatile solids contents. The somewhat lower nitrogen content of the sludges which had lost their nitrifying power (Sludges 10° and 10°–800) might possibly be construed as meaning that non-nitrifying sludges contain less nitrogen. Evidence to substantiate or refute such a conclusion is conflicting. It should be pointed out, however, that in the studies herewith presented, whenever conditions were favorable for the development of non-nitrifying sludges, the sludges were apparently overfed, as shown by the B.O.D. removal data. Such overfeeding probably results in the saturation of the activated sludge with the unoxidized colloidal and suspended matter of the sewage of low nitrogen content, and, consequently, the average nitrogen content of the resulting sludge would be lowered.

Since the economy of the practice of fertilizer production from activated sludge is based primarily on the nitrogen content of the sludge, it is reasonable to assume that any practice which will increase the content of nitrogen in the sludge must be considered in determining the conditions of operation which will yield the greatest net income. The greater quantity of activated sludge produced with low aeration solids, in combination with the higher nitrogen content of the resulting sludge, seems to indicate, on the basis of these experiments, with a 10-hour aeration period, that the lowest aeration solids concentration commensurate with good uniform operation would yield the greatest monetary return.

Conclusions

Comparable B.O.D. removals from sewage can be attained with a wide range of activated sludge concentrations. The use of low concentrations results in the development of sludges with high volatile solids contents and high activities as measured by the base rates of oxygen utilization. Because of the high activity of such sludges, they must be removed rapidly from final settling tanks and kept in contact with dissolved oxygen to keep them in condition. The chief advantage to be gained in using low activated sludge concentrations is the decreased oxygen requirements to stabilize a given B.O.D. load. This is a result of the conversion of large quantities of the available food (B.O.D.) to new sludge growth and, consequently, smaller amounts are oxidized to carbon dioxide, water, and nitrates. The use of high concentrations of activated sludge results in the production of sludges

with lower volatile solids content and lower base rates of oxygen utilization. Such sludges may be kept for much longer periods in the absence of aeration without undergoing serious changes and, as a result, more compact sludges are obtained. These two features constitute the chief advantages to be gained from the use of high sludge concentrations.

The loss of nitrifying power by activated sludges at low temperatures is related to the relative rates at which the organisms responsible for stabilizing the carbonaceous matter and the organisms responsible for stabilizing the nitrogenous matter grow. Rapid growth of the organisms responsible for stabilization of the carbonaceous matter is favored by the lower rates of oxidation (high synthesis rates) at low temperatures and by the ability of the sludge to hold available at all times a large food supply by adsorption and coagulation of sewage solids from suspension and solution. The growth of the nitrifying organisms is hindered because of the slowness with which ammonia nitrogen (their source of energy) can be oxidized at low temperatures, and because of the inability of the sludge to adsorb and hold available appreciable quantities of ammonia nitrogen as has been shown by Ingols (8). Thus, at low temperatures the proportion of nitrifying organisms in the sludge will diminish and the nitrifying ability decrease accordingly.

Summary

The results of simultaneous feeding experiments with activated sludge (concentration 1,000 p.p.m.) at 10, 15, 20, and 25 deg. C. and with activated sludge concentrations of 800, 1,600, 2,400, and 3,200 p.p.m. at 10° C. and at room temperature (approximately 20° C.) and with a 10-hour aeration period, have shown the following:

1. Equivalent B.O.D. removals were obtained under all conditions except with 800 and 1,000 p.p.m. of aeration solids at 10° C.
2. When equivalent B.O.D. removals were obtained, the greatest rates of sludge growth were obtained with the lowest concentrations of activated sludge and at the lowest temperatures.
3. The nitrifying ability of the activated sludges was lost at 10° C. when low concentrations of aeration solids were used.
4. The sludges with the highest volatile solids content were produced with the lowest concentrations of aeration solids and at the lowest temperatures.
5. High nitrogen content of the sludges was favored by low activated sludge concentrations and low temperatures.

Acknowledgment

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CARBON AND NITROGEN TRANSFORMATIONS IN THE PURIFICATION OF SEWAGE BY THE ACTIVATED SLUDGE PROCESS *

III. WITH MIXTURES OF STERILE SEWAGE AND PURE CULTURE ZOOGLEAL SLUDGES

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Studies (1) on the carbon and nitrogen transformations in the purification of sewage with natural activated sludge revealed the occurrence of certain fundamental changes which were identical with both high and low solids concentration. Pure culture, zoogleal floc-forming bacteria isolated from activated sludge were demonstrated (2) to be sufficiently alike morphologically and culturally to be classed as one species or genus. The flocculent masses developed in sterile sewage by this bacterium, *Zooglea ramigera*, simulated activated sludge to a remarkable degree. The destructive action of the zoogleal masses on carbohydrates, proteins, and soaps was also elucidated and the clarifying action of the pure culture sludges on sewage mentioned. In order to evaluate the role of these organisms in the carbon and nitrogen transformations which occurred in the purification of sewage by activated sludge, pure-culture zoogleal sludges Z–1 and Z–2 were developed in sterile sewage to a sufficient concentration of sludge to perform the desired experiments.

Experimental

Pure-culture sludge Z–1 was mixed in two concentrations with cotton-filtered, heat-sterilized sewage to produce mixtures with 1,347 and 526 p.p.m. suspended solids. Sludge Z–2 was mixed with sterile sewage to produce a concentration of 1,777 p.p.m. solids. Six liters of each mixture were aerated in flasks fitted with CO_2-free air supply. The method of sampling and analysis was the same as that followed in studies of natural activated sludges (1), and aeration apparatus was the same as that outlined earlier. (2)

Results

Purification.—The removal of turbidity and B.O.D. from the sterile sewages by the pure-culture sludges Z–1 and Z–2 are found in Figs. 1, 2 and 3. Turbidity and B.O.D. of the sterile sewages were rapidly reduced by the pure-culture sludges. After maximum purification of the sewages, continued aeration of the mixtures produced greater increases of turbidity of the liquor than B.O.D. Pure-culture sludge

* Journal Series Paper, N. J. Agr. Exp. Station, New Brunswick, New Jersey, Dept. Water & Sewage Research.

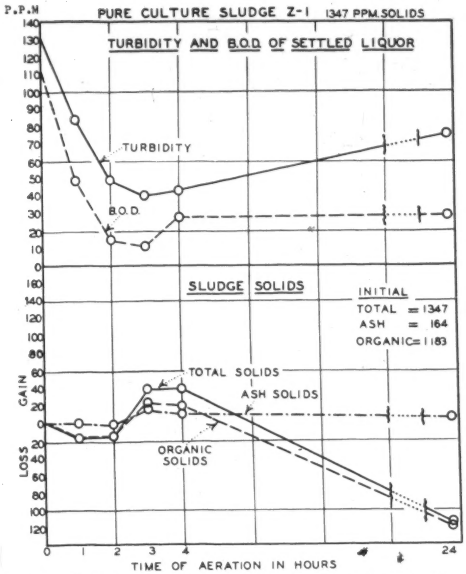

FIG. 1.—Changes brought about by aeration of pure culture sludge Z–1 with sewage in liquor and solids.

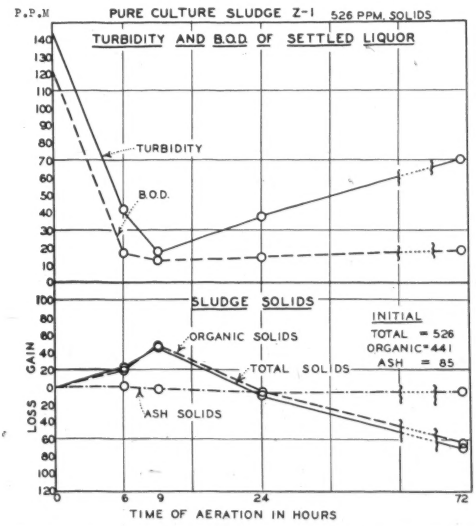

FIG. 2.—Changes brought about by aeration of pure culture sludge Z–1 with sewage in liquor and solids.

Z–2 exhibited a slower clarifying action on sewage than Z–1. In all the mixtures of sludges and sewage the total and organic solids of the sludges increased during early periods of aeration and declined with prolonged aeration.

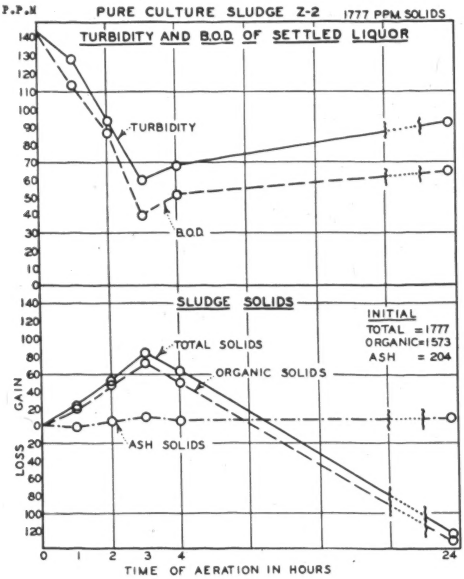

FIG. 3.—Changes brought about by aeration of pure culture sludge Z–2 with sewage in liquor and solids.

CARBON TRANSFORMATIONS

The changes occurring in the carbon content of the pure culture sludge, settled liquor and Seitz filtrate, and the release of carbon dioxide, are found in Tables I, II and III and Figs. 4, 5, and 6. The carbon balances of the sludge-sewage mixtures, representing the sum of carbon in sludge, settled liquor and carbon dioxide evolved, were much more constant at each sampling period than those obtained with natural activated sludge and sewage mixtures described by Heukelekian and Littman (1). The carbon balance of the entire mixture of sewage and sludge Z–1, with a suspended solids concentration of 1,347 p.p.m. (Table I) varied from — 0.4 to + 0.7 per cent from the initial value, with an average variation of — 0.4 per cent. The carbon balance of the low solids mixture of Z–1, Table II, varied from — 0.5 to + 1.5 per cent from the initial value, with average percentage error of + 0.2 per

TABLE I.—*Carbon Transformations in the Purification of Sterile Sewage by Aeration With Pure-culture Zoogleal Sludge Z-1*

Solids Concentration, 1,347 P.p.m.

	Inorganic Carbon	Organic Carbon	CO_2 Produced as Carbon		Total Carbon	Experimental
			At Each Interval	Per Hr.		
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Per cent
0 Hours						
Settled liquor	13.0	92.0			105.0	
Solution (Seitz)	12.0	38.0				
Suspension	1.0	54.0				
Sludge	0	588.0			588.0	
Total Carbon					693.0	—
1 Hour						
Settled liquor	18.0	66.0	0.7	0.7	84.7	
Solution (Seitz)	16.6	31.0				
Suspension	1.4	35.0				
Sludge	0	605.3			605.3	
Total Carbon					690.0	−0.4
2 Hours						
Settled liquor	20.0	48.0	2.9	2.9	70.9	
Solution (Seitz)	18.3	22.6				
Suspension	1.7	25.4				
Sludge	0	615.0			615.0	
Total Carbon					685.9	−1.0
3 Hours						
Settled liquor	24.0	31.0	4.9	4.9	59.9	
Solution (Seitz)	21.2	22.0				
Suspension	2.8	9.0				
Sludge	0	626.4			626.4	
Total Carbon					686.3	−1.0
4 Hours						
Settled liquor	32.0	19.3	6.0	6.0	57.3	
Solution (Seitz)	32.4	20.6				
Suspension	−0.4	−0.7				
Sludge	0	635.0			635.0	
Total Carbon					692.3	−0.1
24 Hours						
Settled liquor	17.0	71.3	49.3	2.5	137.6	
Solution (Seitz)	14.5	27.3				
Suspension	2.5	44.0				
Sludge	0	560.6			560.6	
Total Carbon					698.2	+0.7
Average Experimental Error						−0.4

TABLE II.—*Carbon Transformations in the Purification of Sterile Sewage by Aeration With Pure-culture Zoogleal Sludge Z-1*

Solids Concentration, 526 P.p.m.

	Inorganic Carbon	Organic Carbon	CO_2 Produced as Carbon		Total Carbon	Experimental Error
			At Each Interval	Per Hr.		
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Per cent
0 Hours						
Settled liquor	6.0	125.0			131.0	
Solution (Seitz)	5.8	44.0				
Suspension	0.2	81.0				
Sludge	0	184.0			184.0	
Total Carbon					315.0	
6 Hours						
Settled liquor	12.9	94.0	12.9	2.1	119.8	
Solution (Seitz)	13.2	38.7				
Suspension	−0.3	55.3				
Sludge	0	200.0			200.0	
Total Carbon					319.8	+1.5
9 Hours						
Settled liquor	15.7	47.2	5.0	2.5	67.9	
Solution (Seitz)	13.8	40.0				
Suspension	1.9	7.2				
Sludge	0	250.2			250.2	
Total Carbon					318.1	+1.0
24 Hours						
Settled liquor	14.1	36.2	25.7	1.3	76.0	
Solution (Seitz)	14.5	32.8				
Suspension	−0.4	3.4				
Sludge	0	235.0			235.0	
Total Carbon					311.0	−1.2
72 Hours						
Settled liquor	16.1	56.2	43.8	0.9	116.1	
Solution (Seitz)	15.0	27.0				
Suspension	1.1	23.2				
Sludge	0	177.2			177.2	
Total Carbon					313.3	−0.5
Average Experimental Error						+0.2

cent, while the carbon balance of Z–2 fluctuated even less, —0.1 to + 0.3 per cent, with an average variation of + 0.1 per cent.

Carbon in the pure-culture sludge flocs was entirely organic in nature. In all three sludge-sewage mixtures, aeration produced initially an increase in the organic carbon of sludge coincident with the removal of organic carbon from the settled liquor. Carbon dioxide production rose to a maximum value within the purification periods in all three mixtures and was followed by a decrease in the rate with over-aeration. Aeration prolonged beyond the purification periods caused a loss of organic carbon from the sludge floc which was parallelled by an equivalent release of carbon dioxide. The evolution of carbon dioxide from the sludges was not the only factor responsible for the loss of organic carbon in the sludge, since marked increase in the suspended organic carbon occurred in the settled liquors with over-aeration of the sludges. This was attributed to the deflocculation of the pure culture sludges. The decrease of organic carbon in solution with ae-

TABLE III.—*Carbon Transformations in the Purification of Sterile Sewage by Aeration With Pure-culture Zoogleal Sludge Z-2*

Solids Concentration, 1,777 P.p.m.

	Inorganic Carbon	Organic Carbon	CO_2 Produced as Carbon		Total Carbon	Experimental Error
			At Each Interval	Per Hr.		
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Per cent
0 Hours						
Settled liquor	10.5	112.0	—	—	122.5	
Solution (Seitz)	10.3	51.0				
Suspension	0.2	61.0				
Sludge	0	795.0			795.0	
Total Carbon					917.5	
1 Hour						
Settled liquor	12.0	98.3	0.9	0.9	111.2	
Solution (Seitz)	11.5	46.1				
Suspension	0.5	52.2				
Sludge	0	809.0			809.0	
Total Carbon					920.2	+0.3
2 Hours						
Settled liquor	15.0	69.7	3.6	3.6	88.3	
Solution (Seitz)	15.0	35.0				
Suspension	0	34.7				
Sludge	0	827.0			827.0	
Total Carbon					915.3	−0.2

TABLE III—*Continued*

	Inorganic Carbon	Organic Carbon	CO_2 Produced as Carbon		Total Carbon	Experimental Error
			At Each Interval	Per Hr.		
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Per cent
3 Hours						
Settled liquor	17.0	54.8	6.3	6.3	78.1	
Solution (Seitz)	17.5	30.0				
Suspension	−0.5	24.8				
Sludge	0	841.0			841.0	
Total Carbon					919.1	+0.2
4 Hours						
Settled liquor	15.0	59.8	7.5	7.5	82.3	
Solution (Seitz)	15.0	29.8				
Suspension	0	30.0				
Sludge	0	836.0			836.0	
Total Carbon					918.3	+0.1
24 Hours						
Settled liquor	26.3	89.2	64.5	3.2	180.0	
Solution (Seitz)	27.0	37.0				
Suspension	−0.7	52.2				
Sludge	0	736.0			736.0	
Total Carbon					916.0	−0.1
Average Experimental Error						+0.1

ration of all mixtures was attributed to microbial assimilation of this material by the sludge bacteria. Inorganic carbon, which was found entirely within the Seitz filtrate, increased with aeration in all mixtures during the purification period.

Hourly rate of carbon dioxide production by pure culture sludge Z–1, with solids concentration of 1,347 p.p.m., reached a maximum of 6.0 milligrams of carbon by the fourth hour of aeration (Table I). The same sludge in low concentration reached the maximum rate of carbon evolution of 2.5 milligrams of carbon by the ninth hour of aeration (Table II), while sludge Z–2 in concentration of 1,777 p.p.m. reached a maximum of 7.5 milligrams of carbon in the fourth hour of aeration (Table III). Throughout the entire aeration periods, the average hourly rate of carbon dioxide production per 1,000 p.p.m. sludge solids in the three different mixtures was 1.97 milligrams for Z–1 with high solids concentration; 2.30 milligrams for Z–1 with low solids concentration; and 1.94 milligrams for Z–2.

Nitrogen Transformations

Transformations in the nitrogen contents of the various fractions of pure-culture sludge-sewage mixtures of Z–1 and Z–2 are found in Tables IV, V and VI and Figs. 7, 8 and 9. Nitrogen balances representing sums of nitrate, ammonia and organic nitrogen of pure-cul-

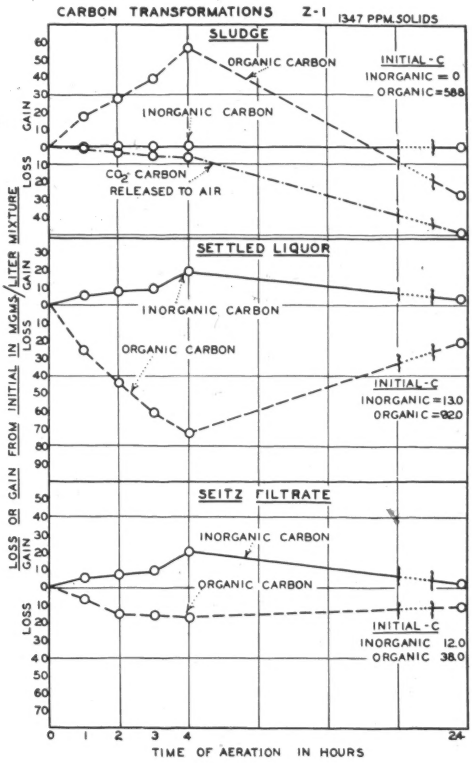

Fig. 4.—Carbon transformations brought about by aeration of pure culture sludge Z–1 with sewage.

ture sludge and settled liquor were quite constant throughout the aeration periods. Fluctuations in the total nitrogen of the three sludge sewage systems averaged — 0.8, + 0.8 and — 0.1 per cent. Nitrification did not occur in any of the sludge-sewage mixtures. Organic nitrogen of the settled liquor was low and did not change much on aeration. Ammonia nitrogen of the liquor decreased during periods

of purification, while organic nitrogen of the sludge increased an equivalent amount. Over-aeration of the mixtures resulted in a decrease of nitrogen content of the sludge, accompanied by increase of ammonia nitrogen in the settled liquor.

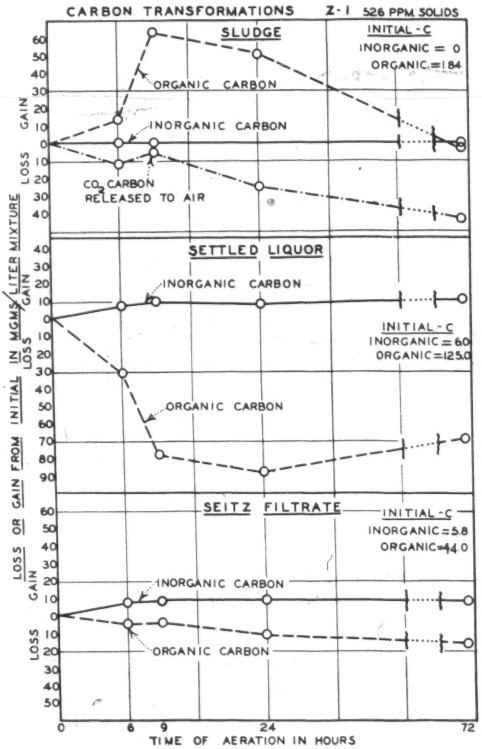

FIG. 5.—Carbon transformations brought about by aeration of pure culture sludge Z–1 with sewage.

DISCUSSION

The oxidizing ability of a pure culture sludge of *Zooglea ramigera* was described by Butterfield (3). During a three-hour aeration period, pure-culture floc was reported to have removed 41 to 84 per cent of the oxidizable materials present in polluted water. Butterfield, Ruchhoft and McNamee (4) also showed that approximately 50 per cent of the 5-day B.O.D. of sewage was oxidized by 5 hours aeration with pure-culture sludges.

In the foregoing experimental work, it was noted that three hours aeration of sewages with pure-culture sludges of Z–1 and Z–2, in concentrations of 1,347 and 1,777 p.p.m., removed 58 to 70 per cent of the turbidity and 67 to 90 per cent of the 5-day B.O.D. Pure-culture sludge Z–1, in concentration of 526 p.p.m., reduced the turbidity 87 per cent

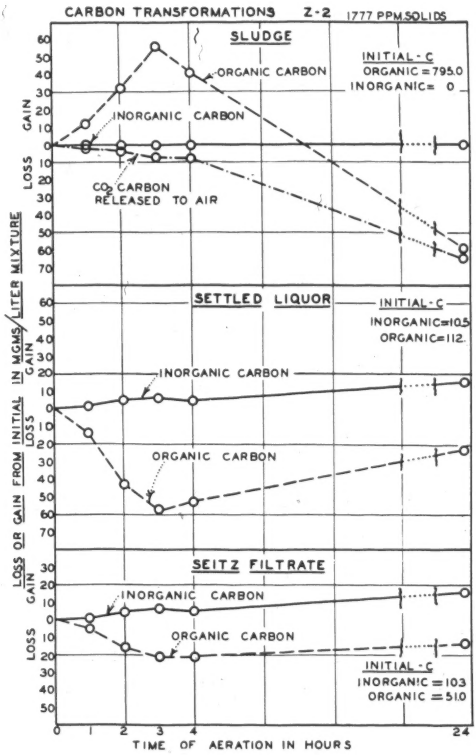

FIG. 6.—Carbon transformations brought about by aeration of pure culture sludge Z–2 with sewage.

in 9 hours of operation and the B.O.D. 89 per cent. Natural activated sludge in concentration of 1,850 p.p.m. was shown (1) to remove 90 per cent of the turbidity of sewage and 81 per cent of the 5-day B.O.D. after three hours of aeration. The same sludge in concentration of 464 p.p.m. reduced turbidity 90 per cent and the 5-day B.O.D. 78 per cent in 9 hours aeration.

TABLE IV.—*Nitrogen Transformations in the Purification of Sterile Sewage by Aeration With Pure-culture Zoogleal Sludge Z-1*

Solids Concentration, 1,347 P.p.m.

	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen	Total Nitrogen	Experimental Error
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Per cent
0 Hours					
Settled liquor	0.3	24.0	4.0	28.3	
Solution (Seitz)	0.3	24.0	0.6		
Suspension	0	0	3.4		
Sludge	0	0	128.5	128.5	
Total Nitrogen				156.8	—
1 Hour					
Settled liquor	0.1	23.0	4.0	27.1	
Solution (Seitz)	0.1	23.0	0.2		
Suspension	0	0	3.8		
Sludge	0	0	128.9	128.9	
Total Nitrogen				156.0	−0.5
2 Hours					
Settled liquor	0.1	22.0	3.2	25.3	
Solution (Seitz)	0.1	22.0	0.4		
Suspension	0	0	2.8		
Sludge	0	0	129.2	129.2	
Total Nitrogen				154.5	−0.4
3 Hours					
Settled liquor	0.1	20.0	5.2	25.3	
Solution (Seitz)	0.1	20.0	0.2		
Suspension	0	0	5.0		
Sludge	0	0	131.0	131.0	
Total Nitrogen				156.3	−0.3
4 Hours					
Settled liquor	0.1	18.0	5.8	23.9	
Solution (Seitz)	0.1	18.0	2.0		
Suspension	0	0	3.8		
Sludge	0	0	133.8	133.8	
Total Nitrogen				157.7	−0.7
24 Hours					
Settled liquor	0.1	20.0	5.9	26.0	
Solution (Seitz)	0.1	20.0	5.6		
Suspension	0	0	0.3		
Sludge	0	0	129.2	129.2	
Total Nitrogen				155.2	−1.0
Average Experimental Error					−0.8

The rapid initial uptake of suspended organic carbon from the sewage previously described in the purification process with natural activated sludge (1), was also evident in the purification brought about by pure-culture zoogleal sludges Z–1 and Z–2. In the purification of

TABLE V.—*Nitrogen Transformation in the Purification of Sterile Sewage by Aeration With Pure-culture Zoogleal Sludge Z-1*

Solids Concentration, 526 P.p.m.

	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen	Total Nitrogen	Experimental Error
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Per cent
0 Hours					
Settled liquor	0.1	23.0	6.0	29.1	
Solution (Seitz)	0.1	23.0	1.0		
Suspension	0	0	5.0		
Sludge	0	0	39.0	39.0	
Total Nitrogen				68.1	—
6 Hours					
Settled liquor	0.1	21.5	5.5	27.1	
Solution (Seitz)	0.1	21.5	1.3		
Suspension	0	0	4.2		
Sludge	0	0	42.1	42.1	
Total Nitrogen				69.2	+1.6
9 Hours					
Settled liquor	0.1	21.0	5.0	26.1	
Solution (Seitz)	0.1	21.0	1.0		
Suspension	0	0	4.0		
Sludge	0	0	44.0	44.0	
Total Nitrogen				70.1	+2.9
24 Hours					
Settled liquor	0.1	15.5	6.4	22.0	
Solution (Seitz)	0.1	15.5	4.5		
Suspension	0	0	1.9		
Sludge	0	0	46.0	46.0	
Total Nitrogen				68.0	−0.1
72 Hours					
Settled liquor	0.1	19.0	5.8	24.9	
Solution (Seitz)	0.1	19.0	4.9		
Suspension	0	0	0.9		
Sludge	0	0	42.4	42.4	
Total Nitrogen				67.3	−1.2
Average Experimental Error					+0.8

TABLE VI.—*Nitrogen Transformation in the Purification of Sterile Sewage by Aeration With Pure-culture Zoogleal Sludge Z-1,*

Solids Concentration, 1,777 P.p.m.

	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen	Total Nitrogen	Experimental Error
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	Per cent
0 Hours					
Settled liquor	0.1	24.0	6.1	30.2	
Solution (Seitz)	0.1	24.0	1.2		
Suspension	0	0	4.9		
Sludge	0	0	172.0	172.0	
Total Nitrogen				202.2	—
1 Hour					
Settled liquor	0.1	22.5	6.2	28.8	
Solution (Seitz)	0.1	22.5	1.3		
Suspension	0	0	4.8		
Sludge	0	0	172.8	172.8	
Total Nitrogen				201.6	−0.3
2 Hours					
Settled liquor	0.1	23.0	5.8	28.9	
Solution	0.1	23.0	1.0		
Suspension	0	0	4.8		
Sludge	0	0	174.2	174.2	
Total Nitrogen				203.1	+0.4
3 Hours					
Settled liquor	0.1	20.0	4.8	24.9	
Solution (Seitz)	0.1	20.0	0.8		
Suspension	0	0	4.0		
Sludge	0	0	175.8	175.8	
Total Nitrogen				200.7	−0.7
4 Hours					
Settled liquor	0.1	18.0	3.2	21.3	
Solution (Seitz)	0.1	18.0	1.5		
Suspension	0	0	1.7		
Sludge	0	0	180.6	180.6	
Total Nitrogen				201.9	−0.1
24 Hours					
Settled liquor	0.1	24.0	4.6	28.7	
Solution (Seitz)	0.1	24.0	2.5		
Suspension	0	0	2.1		
Sludge	0	0	174.0	174.0	
Total Nitrogen				202.7	+0.2
Average Experimental Error					−0.1

sewage with Z–1 it was observed that suspended organic carbon in the settled liquor decreased, during one hour's aeration, from 54.0 to 35.0 p.p.m. (Table I), a loss of 19.0 p.p.m. Inorganic carbon in the liquid increased 4.6 p.p.m. during this period. Only 0.7 milligrams of carbon dioxide was evolved. The organic carbon of the sludge increased

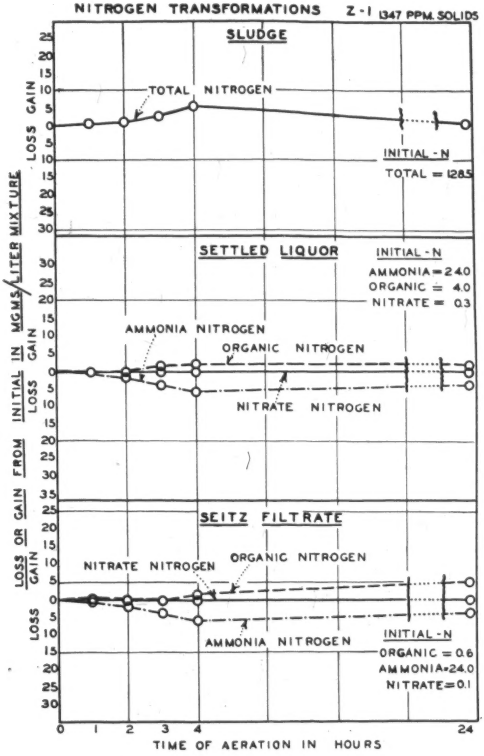

FIG. 7.—Nitrogen transformations brought about by aeration of pure culture sludge Z–1 with sewage.

from 588.0 to 605.3 p.p.m. or an increase of 17.3 p.p.m. indicating that the decrease in the organic carbon of the settled liquor was very closely accounted for by the increase in the organic carbon of the sludge.

The same phenomenon occurred in the low solids mixture of pure-culture sludge Z–1 (Table II) where there was an initial loss of 25.7 p.p.m. suspended organic carbon from the settled liquor. While 12.9 milligrams carbon dioxide was released, there was an increase of 16.0

p.p.m carbon in the sludge. Similarly with Z–2 (Table III) there was a drop of 8.8 p.p.m. suspended organic carbon in the first hour of aeration and organic carbon of the sludge increased 14.0 p.p.m. Only 0.9 milligrams of carbon dioxide was released during this period. The loss of suspended organic carbon from the settled liquor in all these

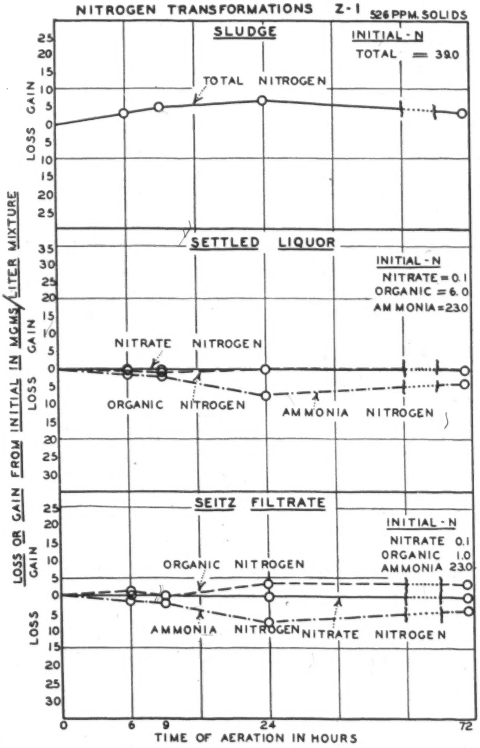

FIG. 8.—Nitrogen transformations brought about by aeration of pure culture sludge Z–1 with sewage.

cases was therefore attributed directly to adsorption of these materials by the pure culture sludges. The loss of suspended organic carbon from the settled liquor continued until the second hour of aeration in the case of the pure-culture sludge Z–1 and until the third hour with the pure-culture sludge Z–2. From the second to fourth hour of aeration of mixtures of both sludges, organic carbon in solution decreased considerably. This was accompanied by an increased rate of carbon

dioxide production and an increase in the amount of organic carbon in the sludge.

It is of interest to note that the carbon changes occurring with the pure-culture sludges were of the same general character as those of natural activated sludge previously reported (1). There was the same

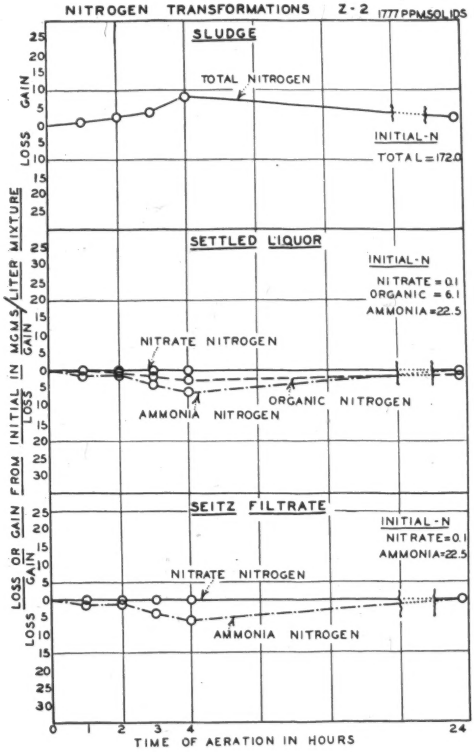

FIG. 9.—Nitrogen transformations brought about by aeration of pure culture sludge Z–2 with sewage.

initial rapid adsorption of suspended organic carbon from the settled liquor by the sludge, resulting in a rapid removal of turbidity and B.O.D., with considerable building up of sludge and an increase in carbon dioxide production. The second phase was also similar, *i.e.*, the oxidation of soluble organic carbon accompanied by further building up of sludge and increase in carbon dioxide production. A third phenomenon resulting in the oxidation of the pure-culture sludge itself

with prolonged aeration beyond the purification period, showed a similar decrease of the organic carbon of the pure-culture sludge accompanied by an increase of organic carbon both in solution and suspension, considerable loss of carbon dioxide, and an increase in turbidity and B.O.D. of the settled liquor.

Organic nitrogen was only a very small part of the total nitrogen in the settled liquor and did not change materially with aeration in the presence of pure-culture sludge. Adsorption of suspended organic nitrogen from the settled liquor by the pure-culture sludges was not evident, most likely because of the small quantity of this type of suspended matter. This too was similar to the behavior of natural activated sludge. Contrary to the highly nitrifying action of the natural activated sludges in the purification of sewage, no nitrification of ammonia nitrogen took place with the pure-culture sludges, since the bacteria of these sludges are incapable of oxidizing ammonia to nitrate. This observation was in accord with the results of Butterfield (3). Like the natural activated sludge, the pure-culture sludges assimilated ammonia nitrogen from the settled liquor during the purification period, and with prolonged aeration the sludges released ammonia nitrogen to the liquor, which accumulated. Ammonia nitrogen was released from natural activated sludge with prolonged aeration (1) but in this case, did not accumulate, since nitrifying bacteria present oxidized the ammonia to nitrates.

From the foregoing discussion of carbon dioxide production by pure-culture sludges, the average hourly rates per 1,000 p.p.m. sludge solids were noted to be 1.97, 2.30 and 1.94 milligrams or an average rate of 2.07 milligrams per 1,000 p.p.m. sludge solids per hour. The average rate of carbon dioxide evolution from natural activated sludge was found to be 4.25 milligrams carbon per 1,000 p.p.m. sludge solids per hour (1). The amount of carbon dioxide liberated by natural activated sludge in the purification of sewage which can be attributed to zoogleal bacteria is therefore approximately one-half of the total. The remainder of the carbon dioxide released by natural activated sludge may be contributed by protozoa and other organisms present. The effect of protozoa on carbon dioxide production from activated sludge will be discussed in a later paper.

The effect of aeration on the per cent carbon and nitrogen and C/N ratio of the pure culture sludges is found in Tables VII, VIII, IX. Aeration of the pure-culture sludges with sewage produced an initial increase in the total and organic solids of the sludge and a simultaneous decrease of organic materials from the liquor. Percentage carbon and nitrogen remained fairly constant throughout the aeration period. During the initial period of aeration the C/N ratio of the sludges increased to indicate a greater uptake by the sludges of carbon than nitrogen. This is explained by the fact that the sewages studied contained approximately ten times as much suspended carbonaceous material as suspended nitrogenous material. Prolonged aeration of

the sludges produced a decrease in the C/N ratio since more carbon was released as CO_2 than nitrogen as ammonia.

From the preceding discussion of carbon and nitrogen changes, it is obvious that differences between low and high solids concentration of the pure-culture sludges in their purifying effect on sewage are found in the time required to bring about these changes rather than in

TABLE VII.—*Changes in Solids, Carbon, and Nitrogen Content of the Pure-culture Zoogleal Sludge of Z-1, Upon Aeration With Sterile Sewage With an Initial Solids Concentration of 1,347 P.p.m.*

Aeration	Total Solids*	Ash*	Organic Solids*	Organic Solids*	Organic Carbon*	Organic Nitrogen*	Organic Carbon†	Organic Nitrogen†	C/N
Hr.	P.p.m.	P.p.m.	P.p.m.	Per Ct.	P.p.m.	P.p.m.	Per Ct.	Per Ct.	
0	1,347	164	1,183	87.8	588.0	128.5	43.7	9.5	4.6 : 1
1	1,330	164	1,166	87.9	605.3	128.9	45.5	9.7	4.7 : 1
2	1,332	163	1,169	87.8	615.0	129.2	46.1	9.7	4.75 : 1
3	1,386	180	1,206	87.0	626.4	131.0	45.2	9.5	4.75 : 1
4	1,387	174	1,203	87.5	635.0	133.8	45.7	9.6	4.75 : 1
24	1,234	170	1,064	86.2	560.6	129.2	45.5	10.5	4.3 : 1

* In sludge.
† On the basis of total solids.

TABLE VIII.—*Changes in Solids, Carbon and Nitrogen Content of the Pure-culture Zoogleal Sludge of Z-1, Upon Aeration With Sterile Sewage With an Initial Solids Concentration of 526 P.p.m.*

Aeration	Total Solids*	Ash*	Organic Solids*	Organic Solids*	Organic Carbon*	Organic Nitrogen*	Organic Carbon†	Organic Nitrogen†	C/N
Hr.	P.p.m.	P.p.m.	P.p.m.	Per Ct.	P.p.m.	P.p.m.	Per Ct.	Per Ct.	
0	526	85	441	83.8	184.0	39.0	35.0	7.4	4.7 : 1
6	547	86	461	84.3	200.0	42.1	36.6	7.6	4.8 : 1
9	572	83	489	85.5	250.2	44.0	44.1	7.7	5.7 : 1
24	515	80	435	84.4	235.0	46.0	45.7	8.9	5.1 : 1
72	456	80	376	82.6	177.2	42.4	38.8	9.3	4.2 : 1

* In sludge.
† On the basis of total solids.

TABLE IX.—*Changes in Solids, Carbon and Nitrogen Content of the Pure-Culture Zoogleal Sludge Z-2, Upon Aeration With Sterile Sewage With an Initial Solids Concentration of 1,777 P.p.m.*

Aeration	Total Solids*	Ash*	Organic Solids*	Organic Solids*	Organic Carbon*	Organic Nitrogen*	Organic Carbon†	Organic Nitrogen†	C/N
Hr.	P.p.m.	P.p.m.	P.p.m.	Per Ct.	P.p.m.	P.p.m.	Per Ct.	Per Ct.	
0	1,777	204	1,573	88.5	795	172.0	44.8	9.7	4.6/1
1	1,800	206	1,594	88.6	809	172.8	45.0	9.6	4.7/1
2	1,830	210	1,620	88.5	827	174.2	45.2	9.5	4.7/1
3	1,860	215	1,645	88.4	841	175.8	45.3	9.5	4.8/1
4	1,845	211	1,624	88.6	836	180.6	45.3	9.8	4.6/1
24	1,655	213	1,442	87.1	736	174.0	44.5	10.5	4.2/1

* In sludge.
† On the basis of total solids.

their type and character. In this respect the pure-culture sludges are again identical with natural activated sludges. The prevalence of the zoogleal floc-forming organism *Zooglea ramigera* in natural activated sludges was pointed out by Heukelekian and Littman (2). The similarity which has been shown to exist between the biochemical changes brought about by natural activated sludge and by pure-culture zoogleal activated sludges in the purification of sewage makes the conclusion possible that *Zoogleal ramigera* is of primary importance in the activated sludge process. The role of the nitrifying bacteria, protozoa and higher filamentous organisms can be considered secondary to the purification process and much less concerned with the principal clarification of sewage brought about by the zoogleal bacterial floc. The relative unimportance of the nitrifying bacteria which may find conditions for nitrification favorable in activated sludge has long been recognized, since nitrification is neither considered an essential desideratum of the purification process, nor does the absence of it impair the purifying action of natural activated sludge on sewage. The secondary role of protozoa, in assisting zoogleal sludges to produce a finished effluent by their removal of free bacterial cells in the liquid, was indicated by Butterfield (3). Results of carbon and nitrogen studies of zoogleal bacteria with pure-culture protozoa will be reported at a future date.

Summary and Conclusions

Three pure-culture zoogleal sludges in concentrations ranging from 526 to 1,777 p.p.m. suspended sludge solids were aerated with sterile sewage for sufficient time to purify and for longer periods to produce definitely over-aerated conditions. Various carbon and nitrogen analyses were made on settled liquor, Seitz filtrate and sludge portions. The results secured led to the following conclusions:

1. Pure-culture zoogleal bacteria, *Zooglea ramigera*, produced flocculent masses in sewage which simulated natural activated sludge and exerted the same clarifying and purifying action on the sewage. Turbidity of sewage was reduced 58 to 70 per cent by these pure-culture sludges and B.O.D. 60 to 90 per cent.

2. The early removal of suspended organic carbon in suspension in the sewage by the pure-culture sludges was identical with the behavior of natural activated sludge. This phenomenon was attributed to adsorption.

3. The initial removal of organic carbon in suspension was followed by removal of organic carbon in solution. This period of biological assimilation by the pure-culture sludges was accompanied by an increased rate of carbon dioxide evolution.

4. During the purification of sewage by the pure-culture sludges, the amount of sludge increased due to (*a*) the initial rapid removal of suspended organic carbon and (*b*) the synthesis of bacterial protoplasm from the oxidation of the adsorbed and soluble materials.

5. Aeration of the sludges beyond the purification periods produced: (*a*) an increase in turbidity, (*b*) an increase of organic carbon in suspension as a result of deflocculation of the sludge, (*c*) a decrease in the organic carbon content of the sludge and (*d*) a release of carbon dioxide almost equivalent to the decrease of organic carbon content of the sludge. These changes were likewise identical with those obtained with natural activated sludge and sewage.

6. Ammonia nitrogen was assimilated by the sludge during the purification period of the sewage while nitrification did not occur. With periods of over-aeration and sludge breakdown, there was a liberation into the liquor of a part of the sludge nitrogen as ammonia, which accumulated. Suspended organic nitrogenous materials were present in the sewage in small amounts and were not materially adsorbed by the sludge.

7. Approximately one-half of the carbon dioxide released by natural activated sludge during sewage purification was attributed to the zoogleal bacteria.

8. As was the case with natural activated sludge, variations in the quantities of pure-culture sludge did not alter the nature of the transformations, but changed the time needed to bring about the transformations.

9. The carbon to nitrogen ratio of pure culture zoogleal sludge was approximately 4.7/1. An increase in the ratio with the progressive purification of the sewage was attributed to a greater uptake from the sewage of carbonaceous than nitrogenous materials.

10. The zoogleal bacterium *Zooglea ramigera*, thriving in sewage in the form of zoogleal flocs and capable of a considerable purifying action on the polluted water is of primary importance in natural activated sludge. The role of nitrifying bacteria, protozoa and higher filamentous organisms can be considered secondary to the purification process brought about by the zoogleal bacteria.

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Plant Operation

IMPROVED SEWAGE CLARIFICATION BY PRE-FLOCCULATION WITHOUT CHEMICALS*

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The solid matter contained in sewage is generally considered to comprise suspended and dissolved solids. In routine sewage analysis, they are reported as such. The suspended solids are further classified into two groups, viz.: settleable and non-settleable solids. These are approximated volumetrically by the well-known Imhoff cone test, or, more accurately, by gravimetric means. In the latter method solids remaining in suspension after a definite laboratory settling period are filtered and weighed in a Gooch crucible.

It has also been recognized that colloidal solids comprise a third solids group, intermediate between the suspended and the soluble solids. Although these colloids may be determined separately either by dialysis or by coagulation, they are usually reported with the true dissolved solids. The latter are obtained by subtracting suspended from total solids in accordance with standard methods of analysis.

In past sedimentation practice very little attention has been paid to the non-settleable and the colloidal solids because it had been thought that these types of solids could not be removed by plain settling, no matter how efficient the settling unit. Numerous laboratory and plant-scale tests run during the past few years have demonstrated, however, that this old concept of primary clarification is erroneous. Supposedly non-settleable and colloidal solids can be made to settle out in a reasonable time under quiescent conditions or in continuous flow tanks by previously subjecting the sewage to a relatively short period of mechanical flocculation. The types of mechanisms employed and their method of operation may be the same as those used in water treatment or sewage chemical precipitation practice.

Classification of Sewage Solids

If the solids made settleable by mechanical flocculation and by chemical treatment are considered as distinct groups, from the standpoint of sedimentation all sewage solids may be broadly classified as follows:

* Presented at the Twelfth Annual Meeting of the New York State Sewage Works Association, New York, N. Y., Jan. 19, 1940.

1. *Suspended Solids*
   - *a.* Settleable.
   - *b.* Mechanically flocculable.
   - *c.* Chemically precipitable.
   - *d.* Filtrable.
2. *Colloidal Solids*
   - *a.* Mechanically flocculable.
   - *b.* Chemically precipitable.
3. *Dissolved Solids*
   - *a.* Chemically precipitable.
   - *b.* Non-precipitable.

All of these solids except the non-precipitable dissolved matter may be removed by one or more steps involving plain settling, mechanical flocculation, chemical treatment and filtration.

Mechanics of Solids Removal

When sewage is subjected to quiescent sedimentation, first the settleable suspended solids drop out. Then a portion of the "mechanically flocculable" solids settle. Part of these may be colloidal solids made suspended and settleable by adsorption on the surfaces of the large suspended settleable particles or by a "salting out" by high concentration of dissolved solids. This "auto-flocculation" effect may be observed in the laboratory when solids are settled in an Imhoff cone and an "after precipitation" of solids occurs on long standing.

In a reasonable time (two hours) about 70 per cent by weight of the suspended solids will usually settle out where the raw sewage suspended solids are about 200 p.p.m. In an efficient continuous flow clarifier, the removals would be somewhat less, say about 60 per cent. This is due to the inability of the lighter flocculable solids to settle because of disturbing flow currents and because of the comparatively lower overflow rates that would necessarily be used in the laboratory due to apparatus limitations. For example, at Aurora, Illinois,* with weak raw sewage of 146 p.p.m. suspended solids, 100 p.p.m. or 68.5 per cent were removed by quiescent settling as against 94 p.p.m. or 64.4 per cent for continuous settling. With strong sewage (286 p.p.m. suspended solids), the laboratory and plant removals were 80 per cent and 76.2 per cent, respectively. These percentage removals will vary depending on the composition of the sewage.

The ratio of plant to laboratory removals may be considered as a measure of true clarification efficiency, as this figure represents results obtained by actual plant operation in relation to the best results obtainable under ideal conditions (quiescent settling). In the case of the Aurora figures cited, this efficiency figure would be $64.4/68.5 = 94$ per cent for the weak sewage, and $76.2/80.0 = 95$ per cent for the strong sewage. This efficiency figure might be applied in comparing settling units at different plants, especially where approximately the same lab-

* From Aurora, Ill., *1932 Annual Report* by W. A. Sperry.

oratory removals are obtained on settling the raw sewage under a standard set of conditions. In our tests the standard laboratory procedure involved the use of a 10 by 6 in. flocculator jar filled with sewage to a depth of about 4½ in. About 250 c.c. of supernatant were siphoned off at a depth of 1 in. after a period of one hour of quiescent settling. Suspended solids were determined in this sample by the usual Gooch crucible method.

When the raw sewage is subjected to a preliminary step of mechanical flocculation, the frequent impacts in the flocculation step render settleable a portion of the supposedly non-settleable matter. This further increases the removal of suspended solids to about 75 per cent under quiescent conditions and to about 72 per cent with continuous flow. These figures compare with removals of 92.5 per cent and 87.5 per cent, respectively, where chemical precipitation is employed. Filtration of the effluent will, in each case, effect a further removal of solids. Typical results that might be expected in practice under these various conditions are shown in Table I. Here the plant efficiencies are taken as

TABLE I.—*Relative Removal Efficiencies of Various Solids Removals Means*
Raw Sewage = 200 P.p.m. Suspended Solids

	Quiescent Settling		Continuous Flow Settling		Plant Efficiency	% Increase in Efficiency
	Effluent Susp. Solids, P.p.m.	% Removal	Effluent Susp. Solids, P.p.m.	% Removal		
Plain Settling	60	70	80	60	86	—
Plaint Settling and Filtration	30	85	50	75	107	24
Flocculation and Settling	50	75	56	72	103	20
Flocculation, Settling and Filtration	20	90	35	82.5	118	37
Chemical Precipitation	15	92.5	30	85	121	41
Chemical Precipitation and Filtration	4	98	15	92.5	132	54

the ratio of the per cent removals under the various continuous flow conditions to the per cent removals by quiescent settling. The per cent increases in efficiency due to flocculation, etc., also relate back to plain settling efficiency. These figures are obtained by subtracting the plant efficiency by plain settling from the efficiencies obtained by the use of flocculation, etc., and dividing by the former.

Illustrative of the effect of mechanical flocculation as against chemical precipitation are results obtained in the laboratory at Cedar Rapids, Iowa. These results gave:

	Susp. Solids. P.p.m.	Per Cent Removal
Raw Sewage	417	—
After Quiescent Settling 60 Min.	197	52.7
After Flocculation 30 Min., Settling 60 Min.	68	83.7
After Chemical Treatment With 1 gr./gal. $FeCl_3$ Flocculation 30 Min., Settling 60 Min.	29	93.0

These figures show that a major portion of the solids removed by chemical treatment is due to purely mechanical effects.

Whether the suspended solids test is a satisfactory means of determining settling tank efficiencies is open to question, except possibly when used comparatively where parallel tests are run. This is true especially when samples are stored, as is done when composite samples are collected and held for 12 to 24 hours before they are analyzed. We have run many tests that show that, with some sewages, entirely different average removal figures are obtained when hourly tests are run immediately when the samples are collected, than when the same samples are composited and a test run on the composite. This indicates that present limitations in standard analytical procedure due to autoflocculation by storage give apparently lower plant removals than are actually obtained in a plant. This also suggests that in plain sedimentation tanks flocculation as well as settling take place simultaneously. Therefore, detention, which is of prime importance in flocculation, and area, which is of primary importance in sedimentation, may both have some bearing on the design of a plain settling unit. However, where the solids are of a flocculent nature, tank surface area is the most important factor that affects settling tank design. This is fully recognized in chemical and metallurgical practice but only to a limited extent in the sanitary field, such as where activated sludge settling is involved. It is obviously inefficient to try to accomplish two opposing steps, *i.e.*, flocculation and clarification, in a single container. Therefore, by separating the steps much more efficient over-all operation may be realized and settling tank volumes cut to a minimum.

Laboratory Experiments

In order to determine the effect of pre-flocculation of raw sewage on various types of material, laboratory tests were run at a number of plants. A small model laboratory flocculator of the type shown in Fig. 1 was used. The paddles of this unit were 3½ in. in diameter and were run at 14 r.p.m. The jar had a capacity of about one gallon. After flocculating and settling for various periods, samples of supernatant liquor were syphoned off for suspended solids determinations. Early in our tests it was found that the flocs produced were so delicate that they were broken up if the sewage were transferred to another vessel after flocculation. Therefore, all samples were settled in the same jar in which they were flocculated. It was also found that the use of small diameter vertical stirrers run at a relatively high speed were absolutely unsuited to this work. The reason for this was that the flocs were broken up when the vertical paddles were run at a speed sufficient to keep the solids in suspension.

Results obtained in these laboratory experiments are shown in Table II. The sewage at these various plants differed widely in quantity and character of the solids. For example: at Coney Island the sewage had a high chloride content due to salt water infiltration; at

Norwalk there was considerable rabbit fur present, due to waste from local hat factories; at Cedar Rapids considerable industrial waste from starch and cereal plants was present; at Ortonville large amounts of creamery waste enter the sewerage system; at Fargo and Morehead, although the sewage was chiefly domestic from a combined system,

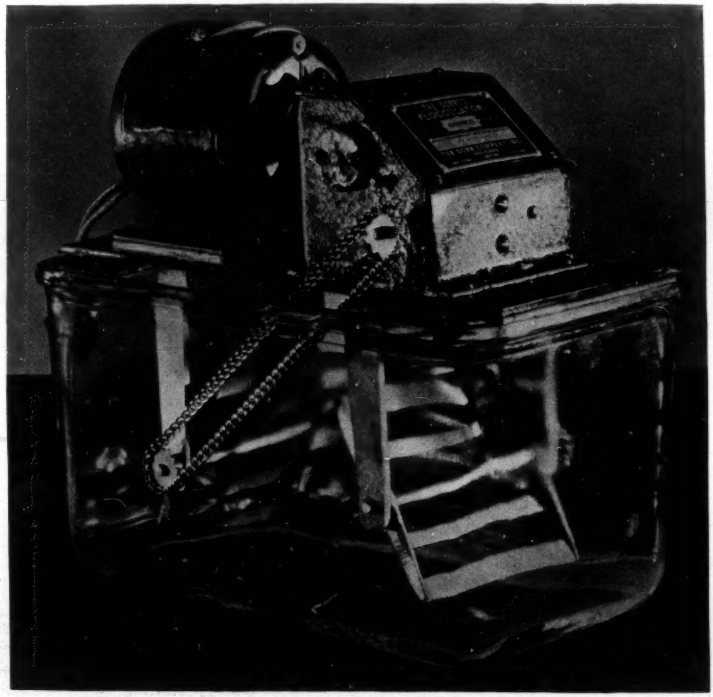

FIG. 1.—Laboratory Flocculator.

high solids were obtained at the plant because of street washings carried to the sewers by melting ice and snow during the winter period when these tests were run. The sewages at Lima, Aurora, Morehead and Sioux Falls were chiefly domestic. In addition to Fargo and Morehead, combined systems are employed at Coney Island, Norwalk, Lima, Aurora, and Cedar Rapids. Sioux Falls has a partially combined system.

These results showed that in all cases mechanical flocculation greatly improved sedimentation results, increased settling efficiency being obtained with increased flocculation periods. In general, how-

TABLE II.—*Laboratory Results—Flocculation of Raw Sewage*

Plant	Coney Island, N. Y.		Norwalk, Conn.		Lima, Ohio		Aurora, Ill.		Cedar Rapids, Ia.		Ortonville, Minn.		Morehead, Minn.		Fargo, N. Dak.		Sioux Falls, S. Dak.	
Suspended Solids	P.p.m.	% Rem.	P.p.m.	% Rem.	P.p.m.	% Rem.	P.p.m.	% Rem.	P.p.m.	% Rem.	P.p.m.	% Rem.	P.p.m.	% Rem.	P.p.m.	% Rem.	P.p.m.	% Rem.
Influent	186		197		171		89		343		896		666		1302		688	
Effluent																		
After No Floc.																		
Settled 20 min.			125	36.5	157	8.2	47	47.2	195	43.1	260	71.0	332	50.1	664	49.0	212	69.3
Settled 40 min.			74	62.4	89	48.0	45	44.5	180	47.6	248	72.4	220	66.9	518	60.2	171	75.2
Settled 60 min.	183	1.6	68	65.4	81	52.7	38	57.3	144	58.0	210	76.6	186	72.0	432	66.8	159	76.9
After 10 min. Floc.																		
Settled 20 min.			125	36.5	76	55.6	37	48.4	193	43.7	138	84.5	112	83.1	502	61.5	119	82.7
Settled 40 min.			72	63.5	68	60.3	19	78.6	190	44.6	176	80.4	90	86.5	324	75.1	108	84.4
Settled 60 min.	102	43.9	60	69.5	62	63.7	52	41.5	103	70.0	165	81.5	97	85.4	316	75.8	95	86.3
After 20 min. Floc.																		
Settled 20 min.			63	68.0	69	59.6	51	42.7	137	60.7	192	78.5	98	85.3	340	73.9	110	84.0
Settled 40 min.			63	68.0	58	66.0	67	24.7	84	75.6	140	84.4	93	86.2	326	75.0	102	85.3
Settled 60 min.	89	50.5	48	75.6	48	72.0	25	72.0	94	72.6	177	80.2	82	87.6	296	77.2	81	88.3
After 30 min. Floc.																		
Settled 20 min.			55	72.6	58	66.0	38	57.3	104	69.7	167	81.3	86	87.0	317	75.6	83	88.0
Settled 40 min.			47	76.2	52	69.5	22	75.3	74	78.5	142	84.0	81	87.8	293	77.4	75	89.2
Settled 60 min.	69	63.0	45	77.0	52	69.5	27	69.7	73	78.8	135	85.0	77	88.4	280	78.4	60	91.3

ever, twenty minutes flocculation time was sufficient to cause the bulk of the suspended solids to settle rapidly. These results also showed that the flocculation not only increased the solids removals but also increased the rate of settling in every case. This would indicate that with flocculation greater removals could be obtained with lower clarifier detention periods than have been used heretofore.

These and other tests also indicate that the effectiveness of preflocculation depended not only on the quantity but also on the quality of the solids.

As a rule, with flocculation settling proceeded more rapidly with higher raw sewage solids concentration unless, of course, the settling rate of the solids was such that rapid settling occurred naturally. Flocculation is usually more effective, therefore, on raw sewage than on settled sewage. Also, it may be greatly assisted by the return to the raw sewage of raw, activated or humus sludge. The presence in the sewage of high amounts of dissolved salts is as a rule helpful, as is indicated by the Coney Island results.

Plant-Scale Tests

Cedar Rapids, Iowa.—In order to verify our laboratory results, it was thought essential to obtain large-scale test data where plain settling could be directly compared with clarification following flocculation. The packinghouse waste pre-treatment plant at Cedar Rapids, Ia., lent itself admirably for this purpose, so with the co-operation of the local officials a test program was initiated at this plant.

The test plant as shown in Fig. 2 consisted of a holding tank 70 ft. dia. by 10 ft. side water depth, a rate-of-flow controller, two clarifiers 50 ft. dia. by 7 ft. side water depth, each having a volumetric capacity of 13,740 cu. ft., and a Flocculator 48 by 13 by 8 ft. water depth. One section of this Flocculator was baffled off so that it was possible to use only 36 ft. of its length, giving a volumetric capacity of 3,744 cu. ft. The Flocculator tank was equipped with four horizontal transverse rows of 6 ft. 6 in. dia. paddles. These were run at a constant speed of 3.15 r.p.m. during the entire test periods. This corresponded to a peripheral speed of 1.07 ft. per second. The plant piping permitted the operation of the two clarifiers in parallel, with the Flocculator preceding only one clarifier. The holding tank and rate-of-flow controller were used to maintain constant flow through the clarifiers during each test run.

Rather than conduct the tests on straight packinghouse wastes, which may not be representative in considering the treatment of domestic sewage, the plant operation was so changed that chiefly domestic sewage was sent to the test plant. In our first series of tests this was accomplished by diverting the packinghouse flow to the main sewage flow at what is known as the Second Street pumping station. This allowed us to take approximately 1,000 g.p.m. of strictly domestic sewage from the Second Street sewer into the test plant. As we needed

about 1,800 g.p.m., this flow was augmented by taking 800 g.p.m. of the mixed flow, which contained 22 per cent of packinghouse waste. Therefore, the percentage of packinghouse waste entering the test plant was cut to about 10 per cent. During our second test series we

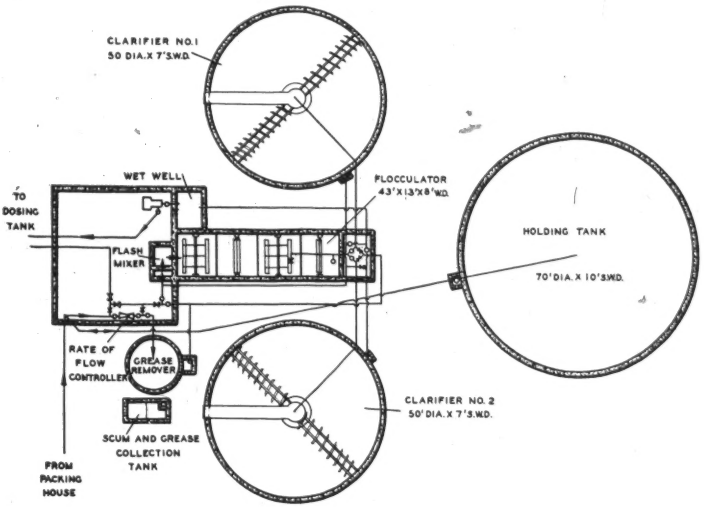

FIG. 2.—Packing house pre-treatment plant—Cedar Rapids, Iowa.

merely diverted all the packinghouse waste to the domestic sewage flow and then pumped a portion of this mixture to the test plant. This gave us a mixture containing approximately 20 per cent of packinghouse waste.

During all test runs, samples of plant influent and of each clarifier effluent were taken every two hours and daily composites made for pH value, settleable solids, and suspended solids analyses. B.O.D.'s were run periodically during the first period, but daily during the second period. All analyses during the first period were run by Dr. Walker, the plant chemist.

In our first test period the flows to each clarifier were varied in order to determine what greater percentage flow could be taken through the Flocculator-clarifier combination without adversely affecting the percentage of solids removals. In the second period equal flows were sent to each clarifier in order to determine the increase in plant efficiency by flocculation as measured by suspended solids removals. The length of each test period was about one month. Summarized results of the suspended solids and B.O.D. data obtained in these tests are given in Table III.

TABLE III.—*Cedar Rapids, Ia., Raw Sewage Flocculation Tests*

Test No.	Raw Sewage		Clarifier Effluents														
			With Flocculation								Without Flocculation						
					Clarifier		Susp. Sol.		B.O.D.			Clarifier		Susp. Sol.		B.O.D.	
	Susp. Sol., P.p.m.	B.O.D. 5 Days, P.p.m.	Flow, M.G.D.	Floc. Det., Min.	Det., Hr.	Over-flow* Rate	P.p.m.	% Rem.	P.p.m.	% Rem.	Flow, M.G.D.	Det., Hr.	Over-flow* Rate	P.p.m.	% Rem.	P.p.m.	% Rem.
1	258	284	1.3	30	1.9	662	113	56.2	242	14.8	1.3	1.9	662	137	46.9	258	9.2
2	208	238	1.3	40	1.9	662	96	53.7	226	5.0	1.3	1.9	662	126	39.3	241	−1.3
3	280	383	1.8	30	1.4	918	123	56.1	290	25.3	0.8	2.9	407	133	52.5	294	23.2
4	271	294	2.0	26	1.25	1040	110	59.3	236	19.7	0.6	3.8	306	121	55.4	244	17.3
5	266	291	0.6	82	3.8	306	82	69.0	188	35.4	0.6	3.8	306	144	46.1	237	18.5
6	257	331	1.0	54	2.5	510	96	62.8	255	23.2	1.0	2.5	510	127	50.6	283	14.7
7	384	368	1.3	41	1.9	662	94	75.6	272	26.1	1.3	1.9	662	125	67.5	297	19.3
8	410	410	1.6	33	1.5	815	113	72.4	300	26.9	1.6	1.5	815	136	66.8	322	21.4

* Overflow rates are given as gal. per sq. ft. per 24 hr.

If we consider the suspended solids test as the criterion of settling efficiency in parallel tests such as these, we can evaluate the increase in efficiency due to flocculation, as already discussed. These figures are shown in Table IV, along with the ratio of flows treated in each

TABLE IV.—*Increase in Settling Efficiency Due to Pre-Flocculation at Cedar Rapids*

Test No.	Raw Sewage Susp. Solids, P.p.m.	Increase in Per Cent Removal Due to Flocculation	Clarifier Detention, Hrs.		Flow Ratio Flow to Flocculator-Clarifier / Flow to Clarifier
			With Floc.	No Floc.	
1	258	19.8	1.9	1.9	1.0
2	208	36.6	1.9	1.9	1.0
3	280	6.9	1.4	2.9	2.35
4	271	7.0	1.25	3.8	3.33
5	266	50.0	3.8	3.8	1.0
6	257	24.1	2.5	2.5	1.0
7	384	12.0	1.9	1.9	1.0
8	410	8.4	1.5	1.5	1.0

case. This tabulation shows that at the same efficiency, clarification capacity was more than tripled by the use of pre-flocculation. It also shows that at the same flow the effectiveness of the flocculation step was increased by increased Flocculator and clarifier detentions where the solids were initially difficulty settleable. Unfortunately during the last two runs the strength of the raw sewage was abnormally high and the solids readily settleable. These results are therefore not directly comparable with those of the other tests. They do check on laboratory observations, that with strong sewages that settle readily by plain subsidence the effectiveness of flocculation is reduced at very short clarifier detentions. In continuous flow tests such as these, the reduced efficiency of flocculation in these latter runs was also probably partly due to the carrying of the light flocculant solids over the effluent weir by the flow currents.

Two factors existed in these tests that favored the flocculation step. These were the maintenance of substantially equal flows during each test and the use of relatively low clarifier overflow rates. A detrimental factor, however, was the disturbing velocity at high flows in the 14 in. siphon feed pipe between the Flocculator and the clarifier. Tests showed that there was a definite floc break-up, especially when the velocity exceeded about 1.5 ft. per second. This was determined by carefully collecting samples of the flocculated sewage from the Flocculator before it entered the siphon, and from the clarifier feedwell after the siphon. Both samples were settled in the laboratory and determinations made of suspended solids remaining in suspension after one hour. Some typical results of these tests are given in Table V.

Laboratory control tests were run during the second test period. Typical laboratory as compared to plant results are shown in Table VI. These results show that it is very essential to select definite laboratory flocculation and settling periods in determining plant efficiencies. Lab-

TABLE V.—*Effect of Siphon Velocity on Floc Break-Up (Cedar Rapids, Ia.)*

Siphon Velocity, Ft./Sec.	Suspended Solids, P.p.m.		
	Before Settling	After Settling	
		Before Siphon	After Siphon
0.9	130–135	49	52
1.4	272–288	87	92
1.8	318–319	73	85
2.3	351–370	81	90

oratory periods of about 30 minutes flocculation and 1.0 hr. settling closely approximates results obtained in actual plant practice at Cedar Rapids with plant flocculation and settling periods of 40 minutes and 2.0 hours, respectively.

TABLE VI.—*Laboratory vs. Plant Suspended Solids Removals (Cedar Rapids, Ia.)*

	Test 1		Test 2		Test 3		Test 4	
	Lab.	Plant	Lab.	Plant	Lab.	Plant	Lab.	Plant
Flocculation Period, Min.	55	53	60	45	29	40	17	34
Settling Period, Hr.	2.6	2.6	2.0	2.0	1.0	2.0	0.75	1.5
Suspended Solids, P.p.m.								
Raw Sewage	276	276	414	414	406	406	472	502
Settled Effluent	102	187	106	223	103	126	232	149
Floc. and Settled Effluent	66	108	62	170	153	168	175	105
Solids Reduction, Percent								
Settled Only	63.0	32.3	74.5	46.2	62.4	58.7	50.9	68.5
Floc. and Settled	76.1	60.8	85.0	59.0	74.7	69.0	63.0	77.8
Plant Efficiency, Percent								
Settled Only	51.3		61.9		94.0		134.5	
Floc. and Settled	96.3		79.1		110.5		152.8	
Increase in Efficiency, Percent, Due to Floc	87.7		27.1		17.5		13.6	

Ypsilanti, Michigan.—Following the Cedar Rapids work, a second detailed series of plant tests was carried out under variable flow conditions at Ypsilanti, Michigan. Here a special type of combination clarifier-Flocculator was installed to operate in parallel with a plain clarifier. The special combination unit termed a "Clariflocculator" is shown in Figs. 3 and 4. It consisted of a Flocculator and a clarifier concentric and circular in plan, the Flocculator compartment being sus-

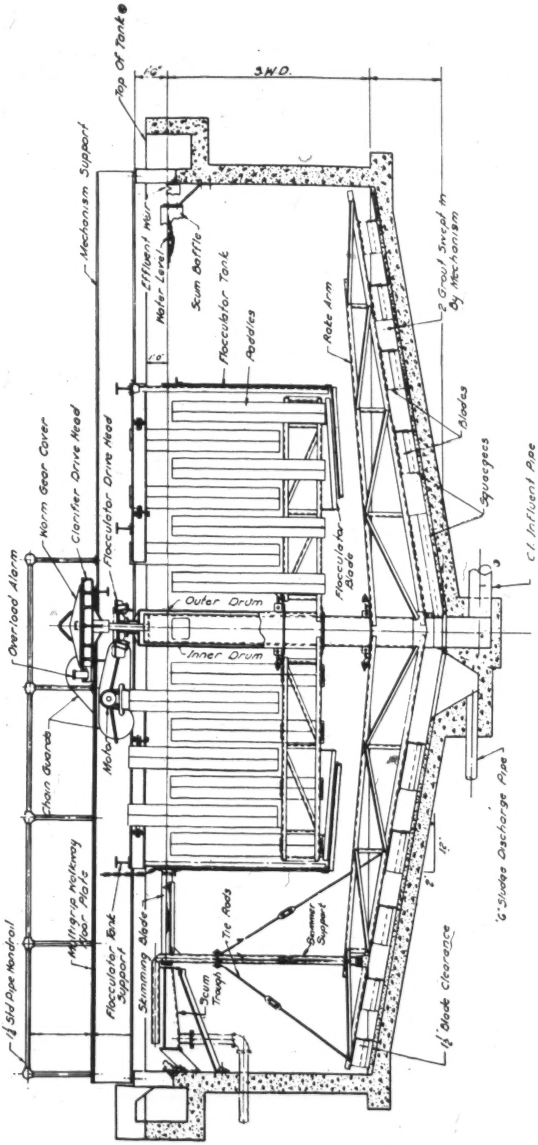

FIG. 3.—Clariflocculator—sectional elevation.

pended in the clarifier above the clarifier floor. Mechanisms were provided in each tank, both mechanisms and the Flocculator tank being supported on beams spanning the clarifier tank. The Flocculator was 18 ft. diameter by 8 ft. 3 in. deep and had a volumetric capacity of 2,070 cu. ft. The clarifier was 40 ft. diameter by 9 ft. side water depth, having a floor slope of 2 in. per foot. The total tank volume was 12,700 cu. ft., so that the clarifier volume was 10,630 cu. ft. The plain clarifier was similar in size and shape to the combination unit, the only difference being that instead of being equipped with a Flocculator for Flocculator tank it was fitted with a standard feedwell. The plant was designed to treat a flow of 1.5 m.g.d. of strictly domestic sewage from a separate system.

FIG. 4.—Clariflocculator—Ypsilanti, Mich.

The Flocculator mechanism consisted of a rotating paddle made up of a series of V-shaped vertical blades extending up from two horizontal arms supported from a vertical drum. Intermeshing with these vertical blades were four sets of downwardly extending stationary V-blades that were supported from beams above the liquid surface. Two substantially horizontal flat blades set at an angle and attached to the lower end of the rotating paddle served to prevent segregation of solids on the floor of the Flocculator tank.

Feed was introduced into center of the Flocculator at its surface through a siphon feed pipe by way of an inner vertical drum, which also served to support the clarifier mechanism arms. It then passed to the clarifier through a central opening in the floor of the Flocculator tank. Originally this opening was 9 ft. in diameter and was baffled by a horizontal plate about 10 ft. in diameter and so spaced that the velocity of flow between the Flocculator and the clarifier was 0.4 ft. per sec. at average design flow.

The purpose of extending the clarifier compartment beneath the Flocculator tank was to allow uniform feeding of the clarifier as far as

possible from the overflow weir, and to utilize as effective settling area and volume that hopper portion of the main tank beneath the Flocculator.

Routine plant and laboratory tests were carried out daily over a period of eight months at this plant. The chief tests were for suspended solids, on catch and hourly composite raw sewage and effluent samples. For convenience, and to reduce change in samples by storage, day (8 A.M. to 3 P.M.) and night (4 P.M. to 7 A.M.) composites were analyzed separately immediately after collection.

Other special tests made consisted of comparisons between the plant and laboratory Flocculator performance. Determinations of the effect of different storage periods on settling efficiency were also made.

Besides plant tests at various average flows and at various Flocculator speeds, changes were made in the construction of the Flocculator tank floor. The purpose of these changes was to determine the least partition area required to prevent the agitative effects produced in the Flocculator from disturbing settling in the clarifier. In all cases, continuous runs of at least one week's duration were made before any changes were made.

Due to low flows entering the plant at the start of our tests, it was necessary to divert a major portion of the flow into one unit at a time. This was done to obtain data with and without flocculation at a reasonable detention period, which we considered to be two hours. Average computed 24-hour composite results of these tests covering a period of ten weeks are given in Table VII. These results show that

TABLE VII.—*Clariflocculator vs. Clarifier—Approx. 2 Hours Detention (Ypsilanti, Mich.)*

	Clariflocculator	Clarifier	Clariflocculator (Flocculator Not Operating)
Total Detention, Hr.	2.06	2.12	2.27
Overflow Rate, Gals. per Sq. Ft. per 24 Hr.	882	861	808
Suspended Solids, P.p.m.			
Raw Sewage	211	230	174
Plant Effluent	77	106	78
Laboratory Settled	61	63	48
Lab. Floc. and Settled	36	38	30
Removals, Percent			
Plant	63.5	53.9	55.2
Lab. Settling	71.2	72.4	72.7
Lab. Floc. and Settling	83.0	83.6	82.7
Plant Efficiency, Percent	89.1	74.4	75.8
Increase in Plant Efficiency, Percent, Over Plain Settling	19.9	—	—

greater removals and improved efficiencies as measured by laboratory comparisons were obtained in the Clariflocculator operating with slightly less detention than the plain clarifier. They also show that with the Flocculator mechanism shut down, the Clariflocculator gave

about the same removal and efficiency as the plain clarifier. This indicates that the method of feeding the clarifier compartment in the special unit was satisfactory.

In view of the stronger sewage being handled when the plain clarifier was under test, it is evident that the 9.6 per cent improvement in removal shown for the Clariflocculator does not adequately show its relative superiority. A fair comparison may be made, however, by comparing the ratio of plant to laboratory removals (plant efficiency) in each case. In these particular tests the increased efficiency due to flocculation is shown to be about 15 per cent, while the per cent increase in per cent efficiency is 19.9 per cent.

The laboratory results were remarkably consistent for all the runs made. Sixty-minute settling periods were used, while with flocculation and settling the periods were 15 minutes and 45 minutes, respectively.

During all these and succeeding plant comparative runs, the Flocculator peripheral speed was held at 1.4 ft. per second. This speed was selected because special tests had shown it to be the most efficient. This is clearly shown in Table VIII, where results of comparison of the

TABLE VIII.—*Effect of Flocculator Speed on Flocculation Efficiency*

Flocculator Peripheral Speed, Ft./Sec.	Suspended Solids, P.p.m.				% Removal			% Efficiency = Plant Floc. Removals / Lab. Floc. Removals
	Raw Sewage	Effluent After						
		Plain Sett.	Plant Floc.	Lab. Floc.	Plain Sett.	Plant Floc.	Lab. Floc.	
0.6	296	63	39	45	78.7	86.8	84.8	101.0
0.9	237	117	57	69	50.6	75.8	70.9	106.8
1.2	308	114	46	60	63.0	84.9	80.4	105.5
1.4	346	120	42	72	65.3	87.8	79.1	110.6
1.6	302	102	38	61	66.1	87.2	79.8	109.2

plant unit with a laboratory Flocculator are tabulated. During these tests the total detention period in the plant unit was held at 2.2 hours so that the flocculation period was 22 minutes. A special technique had to be developed to obtain samples from the bottom of the plant Flocculator without breaking up the flocs. This was best accomplished by the use of a wide-mouth bottle that could be vented by means of a rubber tube extending above the liquid level. The bottle was attached to a pole on a swivel and lowered upside down, as shown in Fig. 5. When the bottle was in proper position, the pinch clamp was opened so that the entrapped air could be slowly displaced by liquid. Then after it was filled, the bottle was turned upright by a second cord attached to the swivel. The bottle was then raised to the surface. In this way floc break-up due to a sudden out-rush of air as the bottle filled was avoided.

Average results of a second series of plant tests with both the Clariflocculator and the plain clarifier operating in parallel are shown in Table IX. These tests were run for twenty-four weeks and are divided up into two periods, one of fourteen weeks at total detentions of

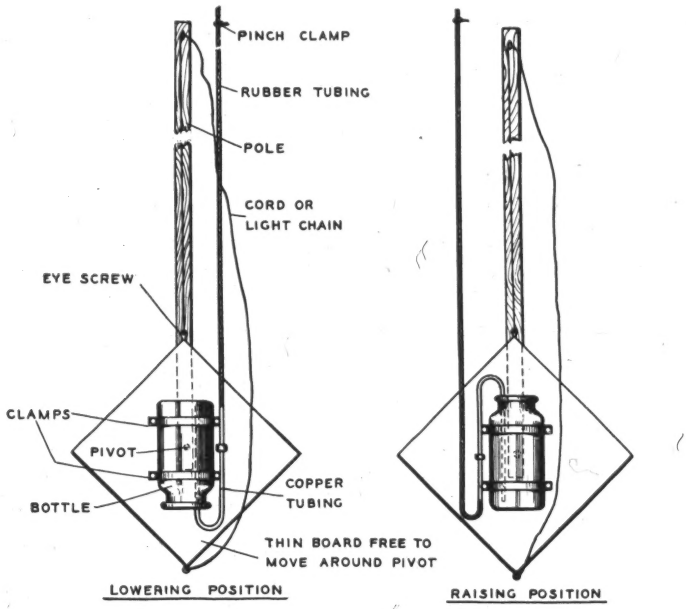

FIG. 5.—Apparatus for collecting flocculated samples below liquid level without breaking up flocs.

approximately two hours, and another at relatively long detentions (about 5 hours). The latter tests were run by the regular plant operating staff.

The results at the lower detentions showed that where about equal flows were put through both units, a 22.9 per cent increase in per cent removals was shown for the Clariflocculator. On the other hand, where about the same removals were obtained it was possible to pass 29.9 per cent more flow through the combination unit. This indicates that at Ypsilanti, within the range of flows used, about 1 per cent increase in removal of suspended solids is equivalent to about a 1.5 per cent increase in flow. With this as a basis, the increased efficiency due to flocculation may be determined even though both removals and flows varied. The average figures show that the Clariflocculator was capable of handling 35 per cent more flow than the plain clarifier to give the

same removal, or it gave a 23 per cent greater removal of suspended solids at the same flow.

The tests at long detentions showed that although the plant unit removals and efficiencies were increased the per cent increase in efficiency for the Clariflocculator decreased. This indicated that at

TABLE IX.—*Clariflocculator and Clarifier Operating in Parallel (Ypsilanti, Mich.)*

	Tests at Short Detention Periods			Tests at Long Detention Periods
	All Tests	Equal Flows to Each Unit (±10% Variation)	Tests with 15–40% More Flow to Clariflocculator	Equal Flows to Each Unit
Total Detention, Hr.				
Clariflocculator	2.10	2.27	1.93	5.41
Clarifier	2.40	2.31	2.51	5.29
Overflow Rate, Gals. per Sq. Ft. per 24 Hr.				
Clariflocculator	858	805	945	337
Clarifier	760	790	718	345
Suspended Solids, P.p.m.				
Raw Sewage	152	155	147	213
Clariflocculator Effl.	69	66	68	54
Clarifier Effl.	78	82	71	73
Lab. Settled	45	47	44	47
Lab. Floc. and Settled	34	36	31	33
Removals, Percent				
Clariflocculator	54.6	57.4	53.8	74.6
Clarifier	48.7	47.2	51.8	65.7
Lab. Settling	69.8	69.7	70.1	77.9
Lab. Floc. and Settling	77.6	76.8	78.9	84.3
Plant Efficiency, Percent				
Clariflocculator	78.2	82.3	76.7	95.7
Clarifier	69.7	67.7	73.8	84.2
Increase in Plant, Percent				
Removals for Clariflocculator	12.1	21.6	3.9	13.5
More Flow to Clariflocculator, Per cent	14.2	1.9	29.9	−0.6
Increase in Plant Efficiency, Percent, for Clariflocculator				
A (At equal flow)	21.6	22.9	23.8	13.1
B (At equal removals)	32.4	34.4	35.8	19.7

Ypsilanti separate flocculation is more effective at lower overall detentions. This is undoubtedly due to auto-flocculation taking place in the plain clarifier. Even at these long detentions, however, a considerable advantage is shown for pre-flocculation.

Additional test runs made showed that no disturbance took place in the clarifier compartment if the bottom circular baffle over the opening in the Flocculator tank floor was removed. It was also found that increasing the bottom opening to 13 ft. in diameter did not affect re-

sults. If the entire floor was removed, however, results obtained in the combination unit were the same as in the plain clarifier.

In general, catch sample tests run daily during the daytime showed better plant removals than did composite samples collected during the same periods. Erratic results were obtained in attempts to show that storing samples for 24 hours or 48 hours affected the suspended solids analysis. Some tests showed little or no difference, while others showed lower removals due to storage.

Field of Application

Mechanical pre-flocculation is apparently effective in increasing raw sewage settling efficiency for most types of sewage. That this is true with sewage encountered in countries other than the U. S. is indicated by numerous tests made in England, Holland and Germany. Typical of these tests are average results obtained on a number of different English sewages as shown in Fig. 6.

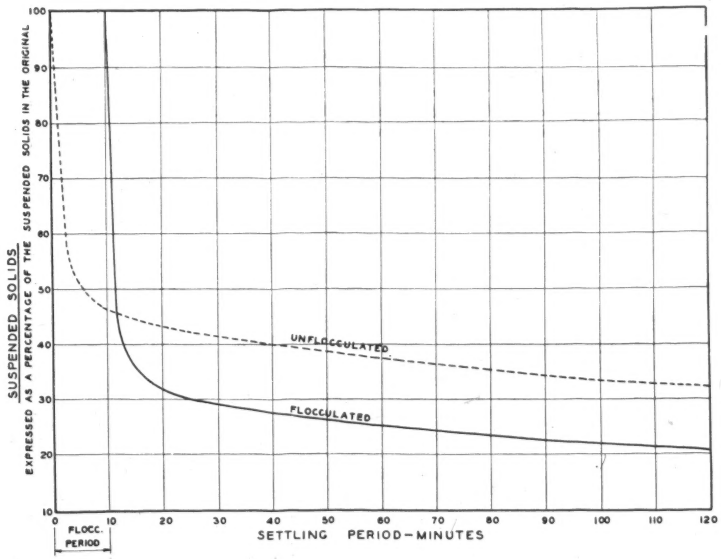

Fig. 6.—Average graphs showing comparative clarification of raw sewage with and without preflocculation. From tests on a number of different English sewages.

Another extensive field of application is in the treatment of trickling filter effluents ahead of settling, particularly where high filter loadings are employed. Results obtained at Sioux Falls using a special type of flocculator and a clarifier with special features are shown in

Table X. The trickling filters were operated at standard low rates and were dosed with a mixture of settled domestic sewage and packing-house waste. These results show a definite improvement in settling due to flocculation. Here again, as these tests were not run in parallel

TABLE X.—*Effect of Pre-flocculation on Settling Trickling Filter Effluent (Sioux Falls, S. D.)*

	Test 1		Test 2	
	Floc.-Clar. (8 days)	Plain Clar. (8 days)	Floc.-Clar. (6 days)	Plain Clar. (4 days)
Flow, M.G.D.	3.36	3.36	3.19	3.04
Detention, Hr.	1.21	1.21	1.27	1.33
Overflow Rate, Gal. per Sq. Ft. per 24 Hr.	1345	1345	1280	1220
Suspended Solids, P.p.m.				
Influent	284	221	81.4	84.6
Effluent	109	137	68	81.2
Lab. Settled	52	78	46.8	57.5
Lab. Floc. and Settled	73	57	38.4	50.8
Removals, Percent				
Plant	51.6	38.0	16.5	4.0
Lab. Settled	74.3	64.7	42.5	32.0
Lab. Floc. and Settled	81.7	74.2	52.8	40.0
Efficiency, Percent	69.4	58.7	38.8	12.5
Increase in Plant Removal, Percent, for Floc.-Clar.	35.8		312.0	
Increase in Efficiency, Percent, for Floc.-Clar	16.5		210.0	

if would not have been possible to compare results on a rational basis if laboratory analyses had not been run simultaneously. This can readily be seen from the wide variation in the per cent increase in plant removal and per cent increase in efficiency figures for the special unit.

An interesting visualization of the action taking place when trickling filter effluent is pre-flocculated may be obtained in Fig. 7. This photo shows samples of trickling filter effluent at a biofiltration plant in Hilversum, Holland, where a Clariflocculator of a type slightly different from that at Ypsilanti is used for final settling. Cylinder 1 contains trickling filter effluent taken at the filter. Cylinder 2 contains the same material at the entrance to the Flocculator tank. Cylinder 3 contains a sample collected at the outlet of the Flocculator after 30 min. flocculation. It will be noted that the flocs in this third sample are very large. They had a high settling velocity.

That mechanical flocculation may even be employed to improve the clarification of activated sludge is shown by the data presented in Table XI. These tests were run at Sioux Falls. In the second test, where the sludge had very poor settling characteristics due to disturbance by gas released by denitrification, flocculation was particularly helpful. These results suggest that mechanical flocculation is more effective than air flocculation. This is probably due to high floc-breaking pe-

ripheral velocities being required in air flocculation to prevent solids segregation.

A comparison of the laboratory tests using a short tube, long tube and Flocculator jar given in this table is of special interest. In the detention tests, settling was carried out under quiescent conditions. The short tube was a standard graduated liter cylinder. The long tube consisted of a glass tube about 3½ in. in diameter by 6 ft. long. It was

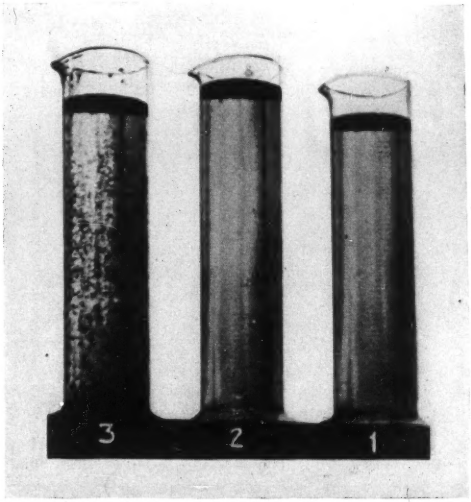

FIG. 7.—Samples of trickling filter (Biofilter) effluent—Hilversum, Holland. Sample 1—At filter outlet. Sample 2—At inlet to Flocculator. Sample 3—At Flocullator outlet.

fitted with tubulatures at one-foot intervals so that samples could be collected from these various levels. These tests show that within the range of overflow rates tried, *i.e.*, from 0.45 in. to 4 ft. per hour (81 to 720 gal. per sq. ft. per 24 hrs.) little difference in settling rate was observed. All the results, however, were better than obtained in the plant, which was being operated at a 9.2 ft. per hr. (1,660 gal. per sq. ft. per 24 hr.) overflow rate.

In the long tube overflow tests, feed was introduced and effluent drawn off continuously, the vertical rise of the liquid being maintained at 7.07 ft. per hr., which is equivalent to 1,270 gal. per sq. ft. per 24 hr. As the material was fed at a depth of 5 ft. and overflowed 4 ft. above this point, the detention period was 0.57 hour. These overflow tests gave results more in line with actual plant operation. In order to run

laboratory tests at the same overflow rate and detention as the plant, it would have been necessary to use tubes about 12 ft. in length.

Where tests were run in a similar manner on raw sewage or trickling filter effluent, it was shown that the effects of wide divergence in overflow rates were more pronounced.

TABLE XI.—*Flocculation of Activated Sludge (Sioux Falls, S. D.)*

Suspended Solids in	Test 1	Test 2
Aerator Mixed Liquor	3,284 P.p.m.	3,570 P.p.m.
Plant Clarifier Effluent, 1.1 hr. detention	26	81
Short Tube Detention, 1.1 hr. detention	18	60
Long Tube Detention, 1.1 hr. detention (1 ft. level)	10	45
Long Tube Detention, 1.1 hr. detention (2 ft. level)	16	46
Long Tube Detention, 1.1 hr. detention (3 ft. level)	15	41
Long Tube Detention, 1.1 hr. detention (4 ft. level)	13	49
Long Tube Detention, 1.1 hr. detention (5 ft. level)	12,160 (sludge)	14,000
Long Tube Overflow, 7.07 ft./hr. overflow rate	26	70
Flocculator Jar Detention, 30 min.	17	62
60 min.	16	54
90 min.	12	43
Flocculated 30 min., Settled 30 min.	11	43
Flocculated 30 mins., Settled 60 min.	6	22
Flocculated 30 mins., Settled 90 min.	6	12

PRACTICAL PLANT DESIGN FEATURES

Based on present plant operating data, it appears that where preflocculation is employed in the treatment of raw sewage, minimum flocculation periods of 30 min. and settling periods of 1.5 hr. should be used. Clarifier overflow rates should not exceed 800 gal. per sq. ft. per 24 hours. Suspended solids removals secured with this combination should be better than where 3.0 hr. of plain settling without flocculation are used. All these figures are based on average daily sewage flow. Results better than 2.0 hr. plain settling should be obtained with 30 min. flocculation, followed by 1.0 hr. settling at about a 1,000 gal. overflow rate. However, in this case the low detention and high overflow rate at peak flows may seriously impair the effectiveness of the combination. Where it is desired to secure high removal of suspended solids generally not obtainable by plain settling alone, 30 to 40 min. flocculation followed by 2 hr. settling at a 600- to 800-gal. overflow rate is recommended. In general it is preferable to design the clarifiers on an area basis, keeping them as shallow as practicable. Flocculator peripheral speeds and transfer velocities of the flocculated material to the clarification zone should not exceed about 1.5 ft. per second. Eddy currents due to change in flow direction, etc., should be avoided as much as possible at the Flocculator discharge and clarifier inlet.

In the treatment of trickling filter effluents about the same flocculation periods should be used as with raw sewage. Clarifier detention based on average flow, however, may be somewhat less and overflow rates proportionately higher. Under average conditions about a 1.0

hr. detention at an overflow rate of 1,000 to 1,200 gal. per sq. ft. per 24 hr. should be adequate.

Economic Considerations

On the basis of increased solids removal, pre-flocculation is of definite economic value as it affords a low cost method for improving clarification efficiency.

Where Flocculator-clarifier combinations are compared with clarifiers alone on the basis of increased capacity at the same clarification efficiency, analyses show a saving in installation costs in favor of pre-flocculation.

Due to the slight improvement in results indicated in activated sludge settling where good settling conditions prevail, it is debatable at this time whether the use of a Flocculator between the aeration and settling steps of an activated sludge plant can be economically justified.

Present Status

That flocculation of raw sewage and trickling filter effluent is becoming increasingly popular is shown by the large number of installations using this principle that have been placed in operation or under construction during the past three years. It is conservatively estimated that over twenty plants are now in operation on raw sewage flocculation alone, using either separate units or combination type machines. Of the latter the 100-ft. diameter unit at Bakersfield, California, is the largest.

Judging from the very favorable results reported at a number of installations originally designed for chemical precipitation, but where pre-flocculation without chemicals is now being employed, it will be a long time before chemicals will be required at these plants.

Summary and Conclusions

This paper presents laboratory and plant data that show that sewage clarification may be improved by the use of pre-flocculation without chemicals. Particular emphasis is placed on the advantages of this principle in the primary treatment of raw sewage.

General conclusions that may be drawn from this work are as follows:

1. Laboratory tests showed that pre-flocculation increased the rate of settling and removal of suspended solids from raw sewage, trickling filter effluent and aeration tank (activated sludge) effluent.

2. Plant tests on raw sewage at Cedar Rapids with constant flows, and at Ypsilanti with variable flows demonstrated that improvements as indicated by laboratory tests may be obtained in actual practice.

3. Plant results on trickling filter effluent at Sioux Falls with constant flows were also in general agreement with laboratory tests.

4. Pre-flocculation may be used to advantage in sewage clarification for either increasing the removal of suspended solids or increasing clarifier capacity or both.

5. The suspended solids test is of questionable value in determining the true efficiency of a settling tank, due to possible change in the samples during storage and because the test does not take into consideration flocculatable and non-settleable solids.

6. A more exact method of measuring the efficiency of a clarifier is to take the ratio of the plant removals to laboratory removals under fixed quiescent conditions. This method might be used in comparing sedimentation units at different plants.

7. At average design flow, minimum Flocculator detentions of 30 to 40 minutes and clarifier detentions of 1.5 to 2.0 hours with a maximum overflow rate of 800 gal. per sq. ft. per 24 hr. are recommended for raw sewage flocculation.

8. For trickling filter effluent treatment, 30 minutes flocculation and 1.0 hour settling at a 1,000 gal. per sq. ft. per 24 hr. overflow rate should be satisfactory.

9. More consideration should be given to area and overflow rates than to detentions in the design of settling tanks where flocculation is employed.

10. Due to the fragile nature of some of the flocs produced by pre-flocculation, the inlet and outlet disturbances should be held to a minimum and velocities in and after the Flocculator should not be allowed to exceed about 1.5 ft. per second.

11. In general, pre-flocculation is economically justified in the treatment of raw sewage or trickling filter effluent ahead of settling. Its use in the case of activated sludge settling is questionable where good settling conditions prevail.

12. An indication of the popularity of pre-flocculation is its extensive use during the past three years. Its more general application with either separate Flocculators and clarifiers or combination type units is predicted.

Acknowledgment

The co-operation and assistance of the city officials and operators at the various plants where laboratory and field tests were made are greatly appreciated. Messrs. J. McIntyre, L. Bradney and J. Max, superintendents of the Cedar Rapids, Sioux Falls, and Ypsilanti plants, respectively, were particularly helpful.

The assistance of Messrs. G. M. Darby and R. B. Thompson of the Westport Mill of The Dorr Company is also acknowledged.

The Cedar Rapids plant was designed by The Howard R. Green Company, Cedar Rapids; additions to the Sioux Falls plant by the Pillsbury Engineering Company, Minneapolis; and the Ypsilanti plant by Shoecraft, Drury and McNamee, Ann Arbor.

Discussion

By Harry W. Gehm

Assistant, Dept. Water and Sewage Research, New Brunswick, N. J.

The mechanical removal of suspended solids from sewage by compact and economical devices offers a definite challenge to chemical treatment. Fischer and Hillman call attention to the fact that the final effluents produced by chemical treatment processes, as compared to a combination of flocculation, sedimentation and filtration, are similar in suspended solids content. By way of further verification we collected data from 23 plants in this country employing chemical treatment processes of various types (Table I). The average suspended solids

Table I.—*Suspended Solids Contents of Effluents, Parts per Million*

Plant	Chemical Treatment, No Filtration	Flocculation Settling and Filtration
Dearborn	24	40
South River	60	54
Sayreville	53	52
Perth Amboy	95	60
Coney Island	49	49*
Lakeland	39	—
Minneapolis	—	52†
Denver	—	28
Raritan	57	49
Somerville	56	—
Goshen	—	58
Essex Fells	21	—
York	55	—
Lakewood	40	—
Grand Rapids	58	—
Dallas	36	
Boulder	26	
Middlesex	44	
Bound Brook	41	
El Paso	54	
Ridgewood	15	
Shades Valley	12	
Danville	44	
Waukegan	40	
New Brunswick	48	
Butler	53	
	—	—
Ave.	44	49

* Pilot Plant tests.

† Calculated from settled effluent and filter guarantees which were met.

content of the effluents produced without filtration was 44 p.p.m. Nine of these plants have been operated with flocculation, sedimentation and filtration, giving effluents containing an average of 49 p.p.m. suspended solids.

It is apparent that the results were practically the same in the case of each process. It is true that the chemical effluents have generally a better appearance than the mechanically clarified ones due to the fact that the solids are in a coagulated rather than in a dispersed state. However, in either condition the solids are oxidizible and the B.O.D. contents of the two types of effluents are substantially the same. It is conceivable that longer periods of flocculation followed by sedimentation and filtration might give almost complete clarification, but by reducing further the suspended solids in the liquor fed to the filters the removal by filtration would be impaired and hence the final results little improved. To increase removals by flocculation substantially over those obtained in one-half hour would require much longer flocculation periods, necessitating a much higher capital cost. The ideal set-up for mechanical clarification appears to be one-half hour flocculation and one to two hours settling, followed by filtration.

Improvement in the mechanical devices involved may put chemical treatment in the background unless it is improved to give, consistently, practically complete clarification without excessive chemical cost, or effluent filtration. Operators refuse to double their chemical costs in order to produce an effluent under 25 p.p.m. suspended solids, as is evidenced by the results presented. Most of the plants have obtained greater removals when they have applied higher chemical dosage but have found the cost of the small additional removal too high. Another factor working against high average removals is the variation in coagulant demand of sewage, which is rather hard to keep up with, especially if industrial wastes are received in the sewage. Others are troubled with sewage that just won't treat well and still others have poor sedimentation facilities. A few plants obtain almost complete clarification without excessive chemical application but these appear to be very much the exception rather than the rule.

The laboratory results on flocculation presented in Dr. Fischer's paper were compared to similar information collected by our laboratory. Inspection of these data showed that removals were a straight-line function of strength; the removal by flocculation increasing as the suspended solids content of the raw sewage increased (Fig. 1). However, the removals obtained with mid-western sewages were greater than those with eastern sewages. We believe that these differences might be due to the character of the waters involved. The eastern sewages originated from soft surface waters while the western came from hard waters. This explanation is reasonable, for tests have shown that the chlorides and sulfates of calcium and magnesium have some coagulating activity when applied to sewage, prior to flocculation and settling. Five hundred p.p.m. of calcium or magnesium chloride as calcium carbonate will increase the removal obtained by flocculation and settling over 50 per cent. We do not believe this to be a salting out effect, however, as it cannot be reproduced with monovalent salts.

The speed of the paddles in flocculations was shown to be of little importance to the process, within reasonable limits. It is fortunate that the higher peripheral velocities are permissible, for in our experience the lower speeds allowed objectionable sedimentation in the Flocculators when raw sewage was treated. This difficulty was practically eliminated by increasing the peripheral velocity from 0.6 to 1.4 ft. per second without impairing the results obtained. In fact better results were obtained when the sludge nuisance was eliminated.

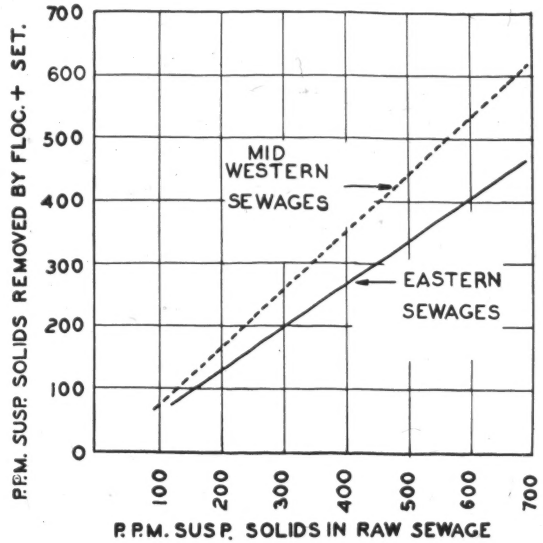

FIG. 1.—Removals of suspended solids obtained by 30 min. flocculation and 1 hr. settling in the laboratory.

The method advanced by the authors for the measurement of the efficiency of sedimentation tanks has definite merit. During experiments at the New Brunswick, N. J., plant, we felt dissatisfied with the usual methods employed. After trying several variations of the usual technique, we devised a method somewhat similar to the one recommended by the authors. We decided that the results obtained were substantially better and were considered more representative than those secured by the old method.

That the removal of non-settleable matter by flocculation depends to any great extent on the quantity of settleable solids is debatable. We know that the removal increases with the suspended solids content of the raw sewage, but as this increases both settleable and non-settleable solids also increase. In general the more of any type of material

present the greater percentage the removal by any process. We know that additional settling can be obtained if flocculation is practiced after pre-sedimentation and that auto-flocculation occurs in Imhoff cones after the settleable solids have dropped out. The stronger the sewage the more of this floc is observed in the cones. It appears, therefore, that the observed increase in removals with the strength of sewage are proportional to the amount of settleable solids present.

Attention should be called to the fact that the floc produced by mechanical flocculation is usually light and fluffy, slowly settling in comparison with a denser and tougher floc produced with chemical treatment.

The writers are to be commended for the thoroughness of their investigation. The tremendous amount of data collected gives the results decided weight. They have demonstrated the value of laboratory tests for prediction of results obtainable by the flocculation process. Every important factor involved was carefully studied and this work will have considerable influence on future design. Our experience has been in agreement with their findings.

PROBLEMS AND PROGRESS IN THE CHLORINATION OF SEWAGE *

By A. E. Griffin and G. A. Campbell

Sanitary Engineers, Technical Service Division, Wallace & Tiernan Co., Inc.

The highly complex nature of sewage, coupled with variations in flow, has long been recognized by all who are connected with the treatment of sewage. Variations of composition and flow have led to a great diversity of treatment methods for the separation of solids from the liquid, and stabilization of the effluent. Chlorine has played a very important role in this work. Through the years experience has shown, and it is now generally recognized, that the hourly variations in flow and strength of sewage are cyclic in character over 24-hour periods.

Attention has recently been called to this fact by several investigations. Although awareness of such variations is undoubtedly widespread among sewage works operators, the importance of these variations upon the efficiency of plant operation is not always given the consideration which it deserves. It is the purpose of this paper to present the results of some studies which have been made at several different plants relative to influent loads, and to point out methods of more adequately meeting the chlorination problems which they create.

Sewage chlorination in the past has generally been of the manual type applied as a pre- post- or in some cases split-chlorination dose. Occasionally it has been found feasible to install automatic chlorination. With this latter method of application the dosage rate follows the variation in sewage flow. These applications of chlorine may be employed to accomplish one or more of a multiplicity of results such as bacterial reduction, odor control, improved sedimentation, reduction in B.O.D., etc. In addition, it is felt that the use of chlorine for grease removal will become increasingly important in the near future, as indicated by the recent activities of the Chlorine Institute.

Plant load studies may be based upon chlorine demand, suspended solids, B.O.D. or similar factors. Plate I illustrates typical 24-hour variations in strength of sewage of a plant serving some 35,000 persons. The curves are based upon chlorine demand and are derived from data by Dr. Symons and his associates at Buffalo. Peak loads occur at approximately 1 P.M. and the curves show the recurring characteristics usually found with sewage influents. Chlorine requirements are shown simply as chlorine demands in the top chart and as total chlorine required for satisfaction in the lower chart, where both flow and chlorine demand are taken into consideration. The lower chart thus indicates the actual working rates of a chlorinator in order to exactly follow the chlorine requirements. Sewage flows are shown on both charts and

* Presented at the Twelfth Annual Meeting of the New York State Sewage Works Association, New York, N. Y., Jan. 19, 1940.

illustrate the usual simultaneous occurrence of peak demands with peak flows and vice versa, storm flows excepted.

Plate II illustrates a similar 24-hour load variation based upon suspended solids. This survey was made by E. T. Killam at the Peachtree Creek Plant in Atlanta, Georgia. Again peak load and flow occurs

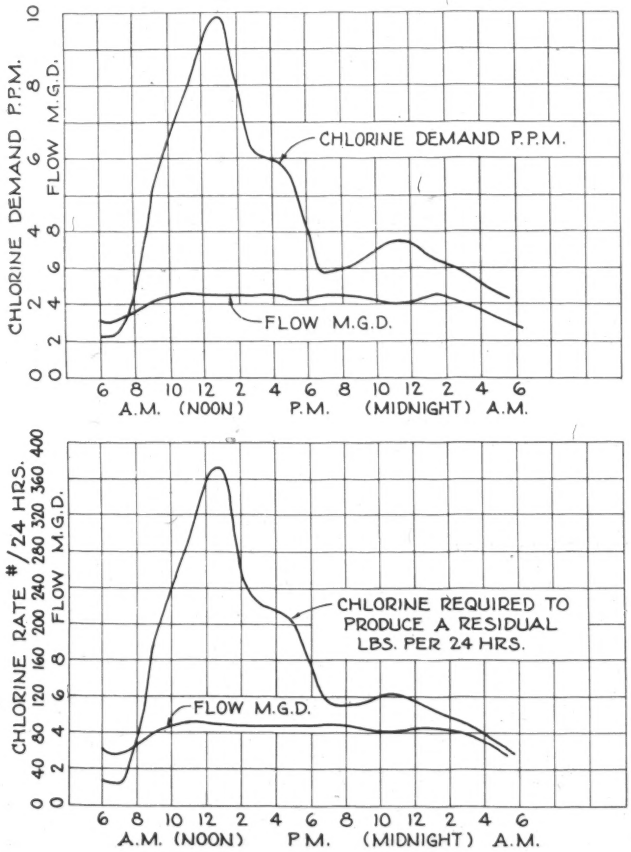
CHLORINE DEMAND P.P.M.
FLOW M.G.D.
0 2 4 6 8 10
0 2 4 6 8
6 8 10 12 2 4 6 8 10 12 2 4 6
A.M. (NOON) P.M. (MIDNIGHT) A.M.
CHLORINE RATE #/24 HRS.
0 40 80 120 160 200 240 280 320 360 400
FLOW M.G.D.
0 2 4 6 8
CHLORINE REQUIRED TO PRODUCE A RESIDUAL LBS. PER 24 HRS.
FLOW M.G.D.
6 8 10 12 2 4 6 8 10 12 2 4 6
A.M. (NOON) P.M. (MIDNIGHT) A.M.

PLATE I.—24 hr. chlorine requirements of plant serving 35,000 people domestic sewage. From data by G. E. Symons, G. E. Terhoeven, W. L. Torrey.

shortly before noon with a minimum in the early morning hours. This chart shows the extensive variation in strength of sewage accompanying relatively small changes in flow, for while the flow doubles the strength of the sewage increases approximately seven-fold.

The third plate represents influent load conditions as found at the Saw Mill River Sewage Plant in Yonkers, N. Y., and includes a brief period during storm flow which shows the reversal of dry weather flow conditions shortly after the storm flow reaches the plant. Whereas increasing dry weather flows are invariably accompanied by increasing strength of sewage, the increasing storm flow is usually accompanied by a decrease in strength of sewage. This particular sewage is both industrial and domestic in nature. With such sewages the discharge of industrial wastes into the sewerage system usually causes an appreciable increase in sewage strength. The second hump in the chlorine

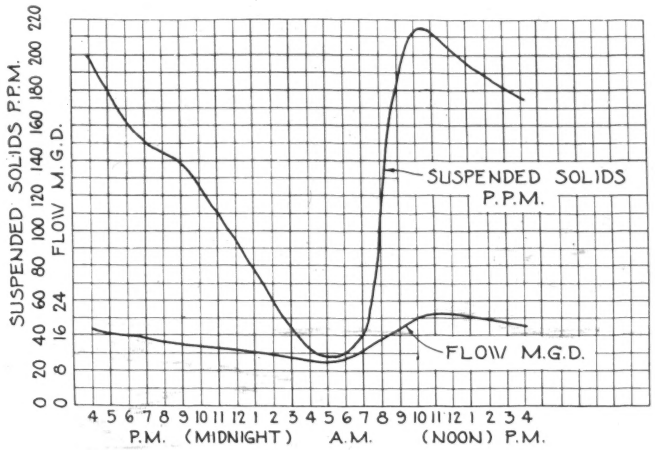
SUSPENDED SOLIDS P.P.M.
0 20 40 60 80 100 120 140 160 180 200 220
FLOW M.G.D.
0 8 16 24
SUSPENDED SOLIDS P.P.M.
FLOW M.G.D.
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
P.M. (MIDNIGHT) A.M. (NOON) P.M.

PLATE II.—Typical hourly variations in strength of sewage based on suspended solids. Peachtree Creek Plant, Atlanta, Ga., May 3–4, 1933. From data by E. T. Killam.

demand curve, occurring at 11:00 P.M. may be an indication of this phenomenon. The time at which such peak loads arrive at the plant depends, of course, upon such physical factors as volume of flow, size of sewer mains and location of plant.

A number of other such examples could undoubtedly be cited but these few instances will serve to illustrate the similarity of load variations existing at sewage plants in general.

In considering these variations in connection with the sewage chlorination problem, at any one plant, several interesting observations may be made. With manual chlorination at a fixed rate there are prolonged intervals of time when either an over or under dose of chlorine is delivered to the sewage. For the plant of small capacity this procedure may be permissible since the quantities involved are relatively small. On the other hand, expenditures for chlorine assume considerable magnitude in the larger plants. Prolonged periods of overdosing are costly

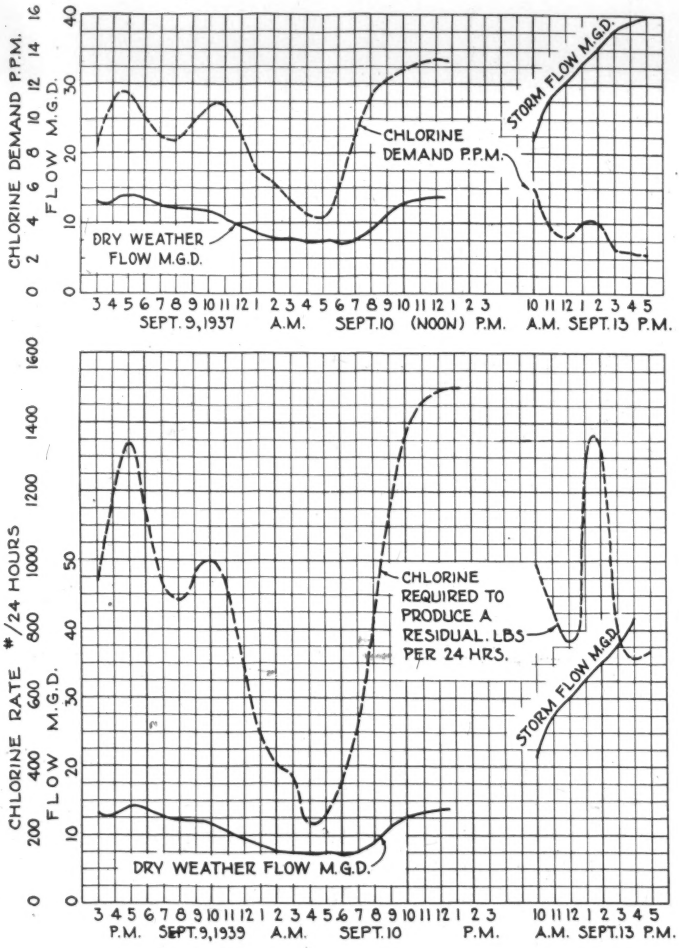
CHLORINE DEMAND P.P.M.
FLOW M.G.D.
CHLORINE DEMAND P.P.M.
STORM FLOW M.G.D.
DRY WEATHER FLOW M.G.D.
SEPT. 9, 1937 A.M. SEPT. 10 (NOON) P.M. A.M. SEPT. 13 P.M.
CHLORINE RATE #/24 HOURS
FLOW M.G.D.
CHLORINE REQUIRED TO PRODUCE A RESIDUAL. LBS PER 24 HRS.
STORM FLOW M.G.D.
DRY WEATHER FLOW M.G.D.
P.M. SEPT. 9, 1939 A.M. SEPT. 10 P.M. A.M. SEPT. 13 P.M.

PLATE III.—Typical 24 hr. chlorine requirements. Sawmill River Plant, Yonkers, New York, Sept. 9, 10, 13, 1937.

and constant supervision and adjustment of dosage rates is essential for efficient operation. Many operators employ two different chlorine dosage rates, one which is maintained during the interval of maximum load, usually during the day, and a second rate during the remainder of the 24 hour period. At best, this is a very rough approximation to the

ideal situation where the demand is always satisfied, with no over or under dosing.

Another method which has been proposed to meet this problem is automatic chlorination. This comprises dosage controlled volumetrically from the flow. However, automatic chlorination of sewage is not always the answer, for, as has been pointed out, a flow change of 2 to 1, for example, may be accompanied by a change in chlorine requirement of 8 or 10 to 1. This leaves much to be desired in the case of volumetric control.

At the present time, two new methods of sewage chlorination are available to handle this situation more adequately and efficiently. The first of these might be called step-by-step chlorination, programmed in such a way that a different dosage rate is maintained at pre-selected intervals throughout each 24-hour period. The particular rate selected for any one interval is based upon the average chlorine requirement as determined by surveys, and from the operator's own experience. In all probability slight modifications in dosage rates may be desirable from time to time for highest efficiency but such a method would more consistently meet the recurring demands encountered.

On Plate IV (upper chart) may be found the 24-hour chlorine demand and requirement curves as found at Highland Park, N. J. Due to a high rate of infiltration there is not much of a flow change at this plant and for this reason the flows are omitted. However, chlorine demands ranged from 0.7 p.p.m. to almost 6 p.p.m. with the maximum strength of sewage arriving at the plant at approximately 11:00 A.M. The lower chart on this plate illustrates how the above mentioned type of control may be applied at this particular plant. Here is shown a step-by-step control system employing 6 dosage rates. Superimposed upon this is the actual chlorine requirement curve discussed previously. It is evident that the step-by-step control follows the requirement curve reasonably well. However, there are still periods of under and over-chlorination as noted. Storm flows which might upset such a control system are fortunately not too frequent or intensive.

In addition to the method just discussed, there has recently been developed a new method of control termed potential chlorination. This means of control embodies the use of an electrode system. In operation, a small amount of sewage is passed through a cell containing a measuring and reference electrode. The potential indication from the cell is transmitted to a suitable recorder which in turn controls the dosage rate of a chlorinator. By this means, the chlorine dosage is adjusted as required in order to produce and maintain a predetermined potential which may be in the low residual range, or, on the other hand, may be at some lower potential level, corresponding to a sub-residual dosage. It is obvious that such a system follows the varying chlorine requirements resulting from changes in both volume and strength of sewage. You will note that this particular chlorine requirement curve was obtained directly from a chlorine flow chart which recorded the dosage rates as dictated to the chlorinator by just such a potential

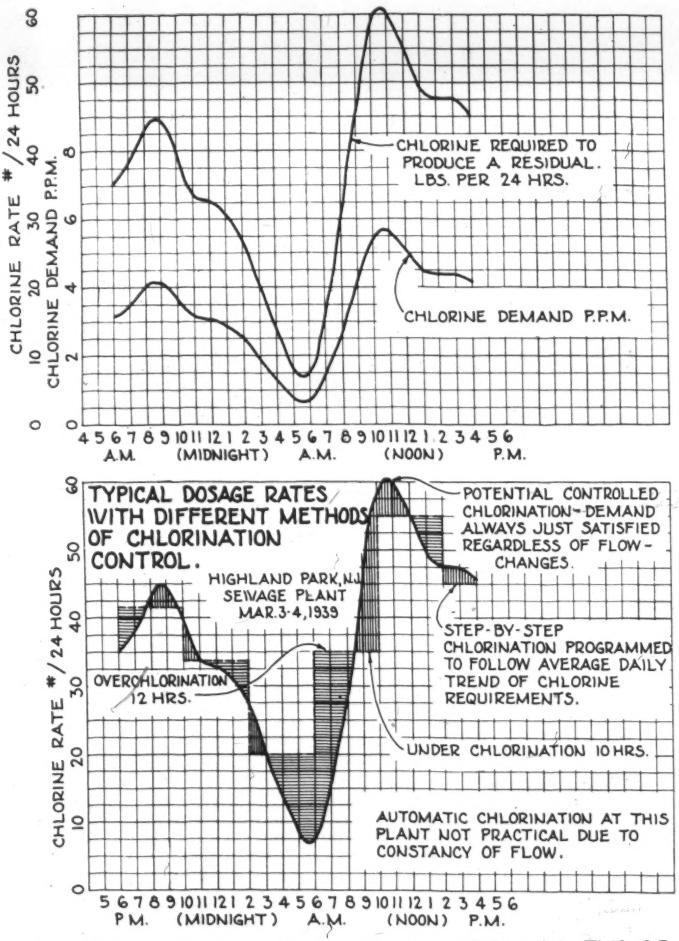
CHLORINE RATE #/24 HOURS
CHLORINE DEMAND P.P.M.
CHLORINE REQUIRED TO PRODUCE A RESIDUAL. LBS. PER 24 HRS.
CHLORINE DEMAND P.P.M.
A.M. (MIDNIGHT) A.M. (NOON) P.M.
TYPICAL DOSAGE RATES WITH DIFFERENT METHODS OF CHLORINATION CONTROL.
HIGHLAND PARK, N.J. SEWAGE PLANT MAR. 3-4, 1939
POTENTIAL CONTROLLED CHLORINATION-DEMAND ALWAYS JUST SATISFIED REGARDLESS OF FLOW-CHANGES.
STEP-BY-STEP CHLORINATION PROGRAMMED TO FOLLOW AVERAGE DAILY TREND OF CHLORINE REQUIREMENTS.
OVERCHLORINATION 12 HRS.
UNDER CHLORINATION 10 HRS.
AUTOMATIC CHLORINATION AT THIS PLANT NOT PRACTICAL DUE TO CONSTANCY OF FLOW.
P.M. (MIDNIGHT) A.M. (NOON) P.M.

PLATE IV.—Typical changes in chlorine requirements over 24 hr. period. Highland Park, N. J., Sewage Plant. High rate of infiltration—flow almost constant at 1.3 m.g.d. Data taken from chlorine flow chart working in conjunction with potential controlled chlorinator.

measuring device. These dosages of chlorine at all times were sufficient to just produce a chlorine residual of 0.2 p.p.m. in the sewage a few minutes downstream from the point of chlorine application. This means of control represents the ideal method, in that both flow and demand changes are met simultaneously. Storm flows or other unusual

conditions are likewise taken in their stride and do not interrupt the normal functioning of this type of control.

In view of the factors that have been discussed, and keeping in mind the various stages of the different sewage processes, it would seem that the larger the treatment works, the greater is the need for vigilant operational control and the more extensive are the benefits to be derived from efficient operation. Such plants would best be served by potential control of any chlorination dosage as this method gives the most consistent results most economically.

For the smaller plants, where the ultimate refinement of control is not strictly essential, a programmed step-by-step method of chlorination seems feasible. Such control is best confined to pre-chlorination doses as recurring load characteristics on influent sewage are usually quite consistent.

Typical load variations at several different plants have been presented. The recurrence of such variations during each 24-hour interval has been mentioned and methods available for most efficiently handling these loads are discussed with particular reference to step-by-step control on a program basis, and potential control.

Proper use of such methods will result in material savings and better operation of the plant.

DISCUSSION OF THE PAPER "PROBLEMS AND PROGRESS IN THE CHLORINATION OF SEWAGE," BY A. E. GRIFFIN AND G. A. CAMPBELL

By Harry A. Faber

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Studies on the chlorine demand of influent sewage loads at treatment plants, and two new methods of proportional chlorine application, have been most competently discussed in this paper presented by Mr. Griffin. Reference has also been made to the use of chlorine for removal of grease from sewage.

Investigation of grease removal methods and the exact significance of grease in sewage treatment processes are subjects which, up to the present, have received relatively little study. Some degree of grease removal is always accomplished incidental to the operation of primary and secondary treatment processes; but only through the provision of a separate unit, designed for such a purpose, is really adequate removal possible.

Systems now used for grease removal generally involve pre-aeration of the sewage with diffused air in a tank or channel which provides a detention period of about 3 minutes. Longer periods of aeration seem to be favored in the design of pre-aeration tanks for recent plants. Subsequent quiescent settling, as in primary sedimentation tanks, is usually advisable in order to obtain adequate removal of grease floated to the surface as scum. Very little data is available to show the degree of grease removal which may be accomplished by such treatment.

The use of chlorine in grease removal was originally investigated as a means of increasing the amount of scum resulting from pre-aeration of sewage. Comparative plant-scale studies showed the amount of scum accumulated could be materially increased by introducing small amounts of gaseous chlorine into the air line supplying the pre-aeration tank. This method of partial chlorination may act by destroying the protective colloid effect of protein material which holds the grease in an emulsified form. Chlorinated air was further studied by Keefer and Cromwell at Baltimore under conditions which enabled careful control of all the factors involved. Their results enlarged upon and completely substantiated indications of the earlier study.

For two years this aero-chlorination method has been in full plant scale use at two Lancaster, Pa., activated sludge plants. At these plants aeration is provided in channels which convey sewage, after removal of grit, to the primary settling tank. The period of aeration is short, averaging 2 to 3 minutes, and chlorine is added from a W. & T. solution-feed vacuum chlorinator at a baffle which is located immediately ahead of the diffuser plates. A number of special studies by Wiest have considerably extended available information as to the exact accomplishments of this process.

In the original studies at Woonsocket, R. I., results indicated the application of about 1.5 p.p.m. chlorine to be responsible for additional yields of grease ranging from 189 to 442 per cent of that obtained by aeration without chlorine. The variation in wet weight of scum was from 1.3 to 14.0 lb. per m.g. with the usual aeration and from 5.3 to 29 lb. per m.g. with chlorinated air.

At Baltimore, it was found that the use of only 1.0 p.p.m. chlorine increased scum production more than two times over that produced by air alone. Chlorine doses of 4.0 and 5.0 p.p.m. produced respectively more than six and more than seven times the yield of scum. The amount of air applied varied from 0.064 cu. ft. per gal. with the short detention times to 0.216 cu. ft. per gal. with the longest detention time.

Results at Lancaster, Pa., show the average amount of scum produced to vary as follows:

Detention alone	1.6 lb. per m.g.
Detention plus aeration	3.0 lb. per m.g.
Detention plus chlorine	3.5 lb. per m.g.
Detention plus aero-chlorination	12.0 lb. per m.g.

The greatest advantage resulting from the use of aero-chlorination, however, was found to be that the total removal of grease was much greater than could be accounted for only as the increase in scum. Apparently the largest fraction of grease settles more completely with heavier sewage solids in the primary settling tank, to be removed with the sludge when this treatment is employed. For corresponding tests, the average total grease removal shown by analysis of raw sewage and

of primary effluent is as follows:

	Per Cent
Detention	38
Aeration	50
Chlorine	41
Aero-chlorination	80

During 1939 the aero-chlorination process was placed in operation at the Cleveland, Ohio, Westerly plant and at the Bellefontaine, Ohio, sewage treatment plant. Installations were also made at two industrial waste treatment plants for removal of wool grease. At one of these careful comparative studies are now being conducted and indicate that, to date, a removal of at least 65 to 70 per cent of the chloroform-soluble material may be accomplished with reasonable doses of chlorine.

In 1940 at least two more plants of the activated sludge type and one utilizing trickling filters will have the aero-chlorination process in operation for grease removal. The use of this process has also been proposed for a large primary sedimentation type of plant to prevent grease in the effluent forming a film or sleek on the surface of the receiving water. Thus, this process appears to offer a new means of approach to the solution of a problem which has received relatively little attention.

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DISCUSSION

BY M. H. KLEGERMAN

Associate, Alexander Potter, Consulting Engineer, New York, N. Y.

That portion of Mr. Griffin's paper dealing with the potential measurement method as a means of controlling sewage chlorination again serves as a reminder that sewage characteristics differ not only from one community to another, but, of much greater importance, that they vary markedly throughout the 24-hour day in any one given community. We are well aware of the hourly variation in sewage flow arriving at a treatment plant. In most instances a specific record of such variation is available and on the basis of such record the operator can well predict the flows his plant may have to handle during certain periods of the day and is, therefore, in a position to adjust his operating devices accordingly. Similarly, we know in a qualitative sense, at least, of variations in sewage "strength" throughout the day. We speak of the "weak" night sewage and the "strong" day sewage, etc. In not many cases, however, is quantitative information available on the hourly variation in sewage characteristics. The work involved in obtaining

and analyzing sufficient number of 24-hour independently composited samples to obtain a dependable record of variations in any given case is not an easy task. This reason probably accounts for the paucity of data in this respect.

The considerable range in hourly variations in sewage properties, particularly as applied to suspended solids and biochemical oxygen demand, and its importance on efficient treatment plant operation has already been effectively illustrated.*

As regards information on the hourly variation in chlorine demand of sewage, the accompanying chart prepared from data obtained by the writer's firm in the course of sewerage investigations in the communities noted, is illustrative of what may be expected. The cases noted represent average flows from 0.25 m.g.d. to 3.49 m.g.d. and populations served from 2400 people to about 40,000. This information and additional data, descriptive of each case, are noted on the chart. As will be observed, factors such as size of collecting system, steep or flat sewer grades, presence or absence of dissolved oxygen and industrial wastes, all of which influence general sewage characteristics, also bear upon that of chlorine demand. Quick sewage delivery to point of treatment appears favorable to lower chlorine demand.

The lower portion of the chart for each case cited, shows hourly variation in chlorine demand as compared to other sewage qualities. The data are insufficient upon which to base broad conclusions, except to note that in the first two cases variation in chlorine demand was rather close to the variation in B.O.D.

Two-hour samples of sewage composited half-hourly in proportion to the flow, taken after passing through bar racks (in Cases I and II) and from the trunk sewer (Case III) were used in the analysis.

Case I. Blohm St. Sewage Plant, West Haven, Connecicut.—Variation in chlorine demand in parts per million, between maximum and minimum, was in the ratio of 15/6 or 2.5 to 1. Taking variation of flow into account, the hourly variation in rate of feed required to meet the chlorine demand is as shown on the middle chart for this case. Here it will be noted that the maximum feed rate required was 250 lb. per 24 hours, and the minimum 48 lb. per 24 hours, giving a ratio of maximum to minimum of 5.2 to 1, with constantly varying requirements throughout the day.

Case II. Prospect Beach Sewage Plant, West Haven, Connecticut.—Variation in chlorine demand between maximum and minimum was in the ratio of 7.8/2.0 or 3.9 to 1. Hourly variation in rate of feed to meet chlorine demand, taking into account variation in sewage flow, was from a maximum of 17 lb. per 24-hours to a minimum of 4 lb. per 24 hours, giving a ratio of 4.25 to 1.

Case III. Trunk Sewer—Rahway Valley Joint Sewer, New Jersey.—In this instance, the variation in chlorine demand between maximum and minimum was in the ratio of 23/4 or 5.75 to 1. The combined effect

* E. T. Killiam, "Hourly Load Variations in Sewage Treatment," *Water Works and Sewerage*, July, 1934.

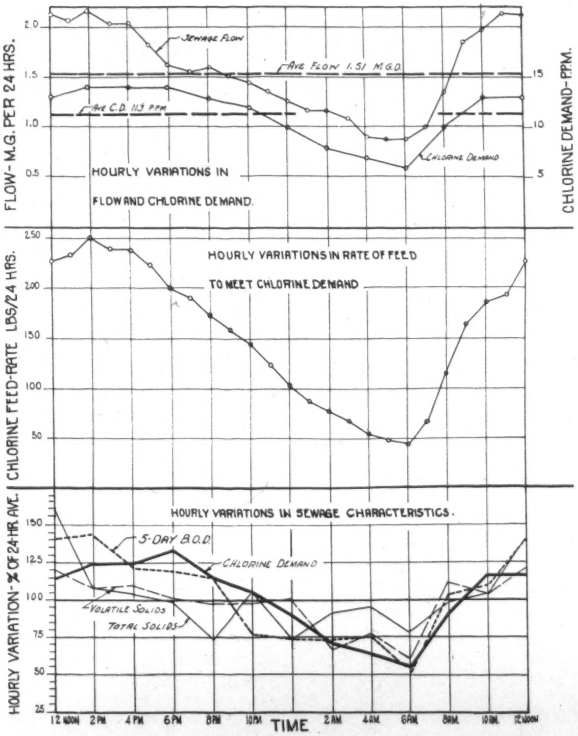
PLANT- BLOHM ST.
CITY- WEST HAVEN, CONN.
DATE- APRIL 11-12, 1935.

POPULATION CONNECTED - 18,600
AVE. SEWAGE FLOW 1.51 M.G.D.

REMARKS: RELATIVELY LARGE COLLECTING SYSTEM- GRAVITY FLOW (SOME PUMPING)
FLAT SEWER GRADES- STALE SEWAGE- SOME IND. WASTES.

TYPICAL ANALYSIS

TOTAL SOLIDS	TOTAL 563 P.P.M.		VOLATILE SOLIDS	TOTAL 333 P.P.M.	
	SUSPENDED 145 P.P.M.			SUSPENDED 120 P.P.M.	
	DISSOLVED 418 P.P.M.			DISSOLVED 213 P.P.M.	
5-DAY B.O.D. 250 P.P.M.	D.O. (ABSENT)	ALK (MG) 168 P.P.M.		PH 6.9	
CHLORINE DEMAND 11.3 P.P.M.					


FLOW- M.G. PER 24 HRS.
SEWAGE FLOW
AVE. FLOW 1.51 M.G.D.
AVE C.D. 11.3 P.P.M.
CHLORINE DEMAND
CHLORINE DEMAND- P.P.M.
HOURLY VARIATIONS IN FLOW AND CHLORINE DEMAND.
CHLORINE FEED-RATE LBS/24 HRS.
HOURLY VARIATIONS IN RATE OF FEED TO MEET CHLORINE DEMAND
HOURLY VARIATION- % OF 24 HR. AVE.
HOURLY VARIATIONS IN SEWAGE CHARACTERISTICS.
5-DAY B.O.D.
CHLORINE DEMAND
VOLATILE SOLIDS
TOTAL SOLIDS
TIME
12 NOON 2 PM 4 PM 6 PM 8 PM 10 PM 2 AM 4 AM 6 AM 8 AM 10 AM 12 NOON

CASE I.

HOURLY VARIATIONS IN CHLORINE DEMAND

PLANT - PROSPECT BEACH
CITY - WEST HAVEN, CONN.
DATE - APRIL 19-20, 1935

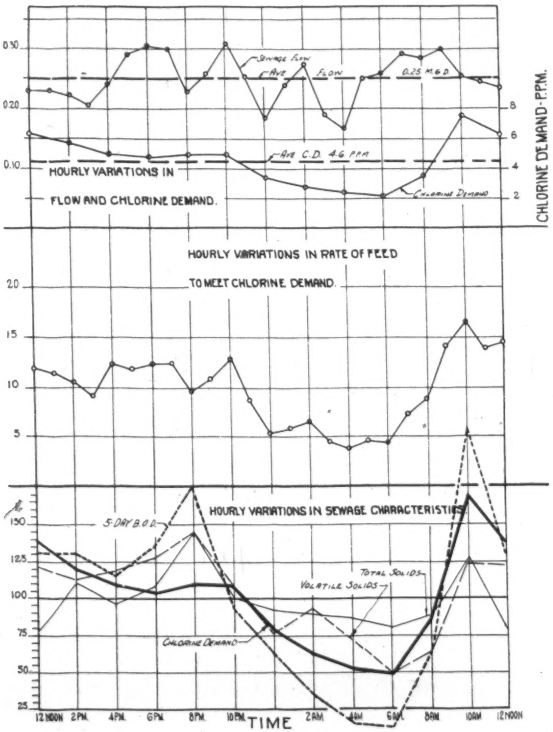
POPULATION CONNECTED 2400
AVE. SEWAGE FLOW 0.25 M.G.D.

REMARKS: SMALL COLLECTING SYSTEM - MAINLY PUMPING - STEEP SEWER GRADES - FRESH SEWAGE - RESIDENTIAL

TYPICAL ANALYSIS

TOTAL SOLIDS	TOTAL	285 P.P.M.	VOLATILE SOLIDS	TOTAL	135 P.P.M.
	SUSPENDED	81 P.P.M.		SUSPENDED	64 P.P.M.
	DISSOLVED	204 P.P.M.		DISSOLVED	71 P.P.M.

5-DAY B.O.D. 85 P.P.M. D.O. (3.9 MIN. - 7.0 MAX.) ALK (M.O.) 104 P.P.M. PH 6.8
CHLORINE DEMAND 4.8 P.P.M.


HOURLY VARIATIONS IN FLOW AND CHLORINE DEMAND.
SEWAGE FLOW
AVE. FLOW
0.25 M.G.D.
AVE. C.D. 4.6 P.P.M.
CHLORINE DEMAND
CHLORINE DEMAND-P.P.M.
HOURLY VARIATIONS IN RATE OF FEED TO MEET CHLORINE DEMAND.
HOURLY VARIATIONS IN SEWAGE CHARACTERISTICS
5-DAY B.O.D.
TOTAL SOLIDS
VOLATILE SOLIDS
CHLORINE DEMAND
TIME
12 NOON 2 P.M. 4 P.M. 6 P.M. 8 P.M. 10 P.M. 2 A.M. 4 A.M. 6 A.M. 8 A.M. 10 A.M. 12 NOON

CASE II.

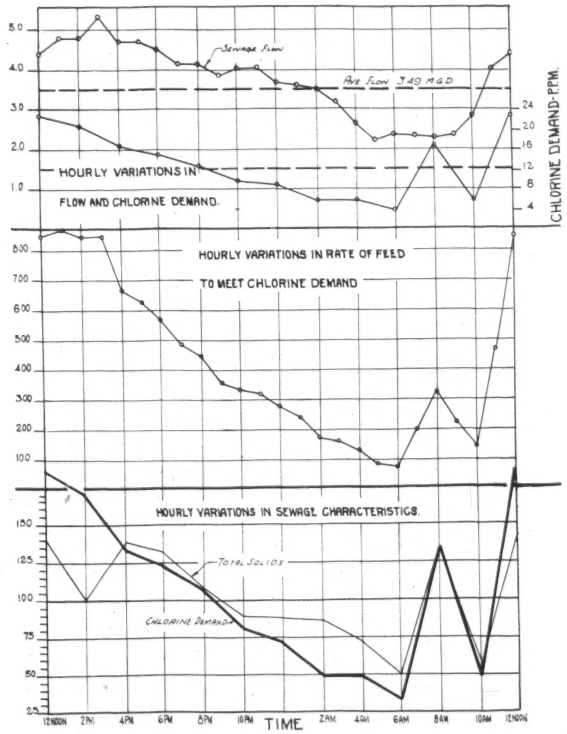
TRUNK SEWER - RAHWAY VALLEY JOINT SEWER	POPULATION CONNECTED —
CITIES* RAHWAY, GARWOOD, ROSSELLE PK, KENILWORTH, CRANFORD, WESTFIELD, SPRINGFIELD, CLARK, WOODBRIDGE	AVE. SEWAGE FLOW 3.49 M.G.D.
	DATE JULY 23-24, 1934.

REMARKS: LARGE COLLECTING SYSTEM - GRAVITY FLOW - SOME IND. WASTES.

TYPICAL ANALYSIS* *

TOTAL SOLIDS	718 P.P.M.	ALKALINITY M.O.	259 P.P.M.
SUSPENDED SOLIDS	258 P.P.M.	PH	7.3
TURBIDITY	275 P.P.M.		

*NOT ALL CONNECTED
**NOT COMPLETE



CASE III.

of flow variation and chlorine demand variation in this case results in a variation of rate of feed of chlorine from a maximum of 880 lb. per 24-hours to a minimum of 80 lb. per 24-hours, giving a ratio of 11.0 to 1. The varying feed rates required for a day's operation are particularly striking in this instance.

Thus, in the chain of refinements gradually being developed in sewage treatment plant and equipment design, as well as in operation, there appears to be justification for considering improvements in the technique of chlorination control—probably the least suspected operation requiring improvements; and the basis for such improvement lies principally in the realization that the chlorine requirements of sewage—let us say for disinfection, as an example—are constantly varying throughout the day. For most efficient disinfection, therefore, it is not sufficient to adjust the chlorinator, to feed chlorine at a "pre-determined" constant rate during the day hours and another "pre-determined" constant rate during the night hours. Nor is it sufficient to test sewage samples at substantial intervals of time for chlorine residuals and adjust the feed rate accordingly. Ideally a control method, as described by Mr. Griffin, which will continuously integrate both variations in chlorine demand and sewage flow so as to maintain as nearly as possible a continuous constant residual of chlorine, would result in substantial chlorine economies. The constant change in chlorine demand and variation in sewage flow, as illustrated by the cases cited, amply justifies such a control.

Industrial Wastes

THE TREATMENT OF WINERY WASTES AT GLENELG, SOUTH AUSTRALIA

By H. J. N. Hodgson and J. Johnston

Engineer and Chemist, respectively, Engineering and Water Supply Department, South Australian Government

The sewerage system of Adelaide and suburbs, which is under the control of the Engineering and Water Supply Department, a State Government Department, embraces three separate drainage areas, each of which has its own treatment works, and these are located at Islington, Port Adelaide and Glenelg, respectively.

The only works touched upon in this paper is that at Glenelg, which is an activated sludge plant with separate digestion of sludge.

The sewage from the Glenelg Drainage Area is almost wholly of domestic origin, the only considerable exception being a very difficult trade waste contributed by a large winery located within the drainage area. The wastes from this winery, which were admitted to the sewerage system in 1932, have made treatment of the sewage difficult and at times practically impossible, and so it has been necessary to consider the question of treating these wastes separately from the sewage.

The experimental work carried out on the problem of the separate treatment of these wastes, and the type of treatment plant evolved, forms the subject matter of this paper.

Introduction.—The climate and the soil of South Australia are particularly suited to the cultivation of vintage grapes, and this State is responsible for over 75 per cent of the total Australian wine production. In the early days of the settlement, Adelaide, the State capital, was surrounded by vineyards, but viticultural activities are now located in various country centres. However, some of the smaller wineries have remained and have become enveloped in the suburban outgrowth of Adelaide. The particular winery, the treatment of wastes from which forms the subject of this paper, is the largest connected to the sewerage system, with an output of some 800,000 Imperial gallons of wine and brandy spirits per annum. It is significant that a rapid expansion of the activities of this winery has occurred since its connection to the sewerage system, and even grain spirit distillation during the non-vintage season is now considered a possibility. Obviously the ready disposal of wastes has enabled the continuance and expansion of the industry in a built-up area, and this has offset the somewhat longer haulage to the works. It should be explained here that a considerable percentage of the fruit used for wine making is grown at distances up to 20 miles from the winery, and has to be hauled to the works.

Origin of Wastes

The grapes commence to ripen about the end of February, and during the latter part of March and the beginning of April the vintage is in full swing. Operations at the winery may be divided into three sections.

1. Wine making.
2. Brandy spirits distillation.
3. Bottling and kegging the above products.

The relationship of these various processes to each other is seen from Fig. 1.

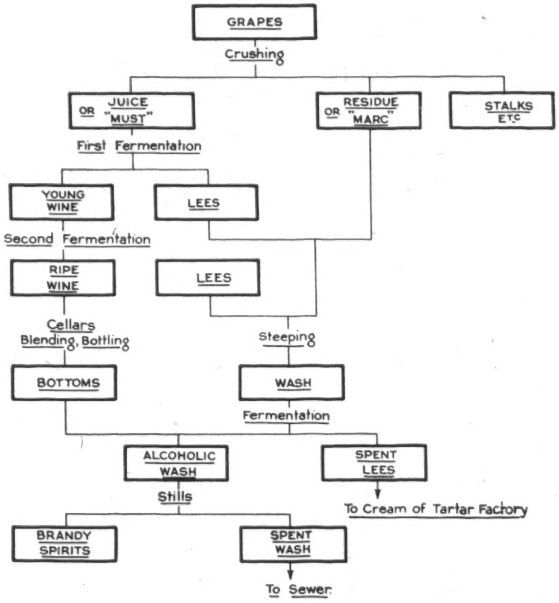


Fig. 1.—Chart of winery operations.

Wine Making.—The grapes are crushed and the stalks and ligneous material rejected, while the expressed juice or "must" which contains 20 to 30 per cent of fermentable material together with the pulp of skins, pips, etc. is pumped into fermentation tanks. The crushing may take place in one, two or three stages, depending on the nature of the grapes, sugar content and type of wine desired. The residue from the final crushing is termed the "marc." The must undergoes a vigorous first stage fermentation for from three to eight days, after which the

yeasts, skins, etc., largely settle to the bottom, constituting the "lees." The young wine is then transferred to wooden vats and allowed to undergo a slow fermentation which may extend into months. At the end of this fermentation period most of the suspended matter has settled, the tartaric acid being precipitated as crude potassium hydrogen tartrate on the sides and bottom of the vat. The ripe wine, as it is now known, is aged and blended in the cellars to develop the requisite aroma, flavour and body for consumption.

Wastes.—The wastes from this section are mainly crushing losses, spray, floor clean-ups, spillage, etc., and are relatively small in quantity and confined principally to the actual crushing season.

Brandy Spirits Distillation.—The lees are combined with the marc and other residues and are steeped in water to extract the maximum amount of sugar. The resultant wash is fermented. After conversion of the remaining fermentable material into alcohol, this wash, which ranges from 4 to 10 per cent alcohol, is distilled to produce brandy spirits. The residue remaining in the fermentation tanks is sent to the cream of tartar manufactory to be worked up for tartaric acid.

Wastes.—The de-alcoholised waste, or spent wash, consisting of yeasts, skins, pips, organic acids, etc., is discharged to the sewerage system, and is really the only waste which concerns the sewage treatment works since it constitutes some 85 per cent by volume of the winery discharge and 98 per cent of the load.

Bottling and Kegging.—The casks and bottles are washed with weak caustic soda solution, the casks being disinfected with sulfur dioxide, steamed and waxed.

Wastes.—The wastes from this section are negligible as far as their effect upon the treatment processes at the sewage works is concerned.

Amount of Wastes.—During the 1936 season gaugings were taken of the total discharge from the winery, which averaged 17,000 Imperial g.p.d. per week of six days, with a peak of 24,000 Imperial g.p.d. during the main crushing season. A vintage 2,500 to 3,500 tons or more of grapes may be processed, each ton resulting in 200 to 250 gallons of wastes. These gaugings include bore-water used to dilute the spent wash from the brandy stills, and also a domestic sewage flow of 1,300 Imperial g.p.d. The net flow would, therefore, be 12,000 and 16,000 Imperial g.p.d., respectively. This dilution of the spent wash represents an attempt to cool the wastes prior to their discharge to the sewer, the temperature being reduced from approximately 210° F. to 150° F. It has a negligible effect upon the reaction of the wastes. The whole question of the treatment of these wastes has been under consideration almost since the inception of the sewage treatment works, and consequently to date the Department has not insisted on any form of treatment, pH adjustment or regulation by the industry, pending the results of these investigations.

After mid-May when the vintage season has closed, the "still" remains in operation intermittently until August or September, operating

on dried fruit washes, the quantity of wastes during this period rarely exceeding 4,000 Imperial g.p.d., and being confined to three or four days per week.

Though the volume of wastes discharged from the winery during the season is fairly consistent, their composition is very variable. This has been one of the difficulties encountered during the experimental work, and one of the advantages of chemical pre-treatment is that it enables an approximate equalization of loading to be achieved, since in this section the degree of treatment can be varied to suit the waste. Table I

TABLE I.—*Analysis of Winery Waste and Dry Weather Flow Sewage*

	Winery Waste	D.W.F Sewage
5-Day B.O.D., p.p.m.	20,000	450
Suspended solids, p.p.m.	—	390
Total solids, p.p.m.	20,000	3,200
Loss on ignition, p.p.m.	16,000	900
Fixed residue, p.p.m.	4,000	2,300
Fehling reductants (as glucose), p.p.m.	2,500	—
Fixed acids (as tartaric acid), p.p.m.	1,100	—
Volatile acids (as acetic acid), p.p.m.	44	—
Ammonia—N_2, p.p.m.	—	48
Organic—N_2, p.p.m.	—	35
Reaction, pH	3.7	8.0
Temperature, ° C.	67	22

shows the general characteristics of the winery waste during the season, and also those of a typical sewage into which the wastes at present discharge.

EFFECT ON SEWAGE TREATMENT

In order to appreciate the effects which this relatively small discharge has on the sewage treatment works the following facts must be considered:

a. The sewerage system is a separate one, and the sewage is almost wholly of domestic origin. The tributary population is 59,000, and the dry weather flow about 23 gallons per head per day. On this basis the wastes approximate 1.0 per cent by volume of the sewage flow.

b. The treatment works are situated with respect to the reticulation system so that practically all the sewage is delivered coincidently to the works. The sewage is definitely fresh, the H_2S rarely exceeding 3.0 p.p.m.

c. Being from a residential area, the sewage flow and loadings show marked hourly variation, dry weather flows ranging from 2,000 g.p.m. to under 200 g.p.m. in the early hours of the morning.

d. The winery season occurs during what is normally the dry-weather flow period for the area.

e. The treatment adopted at the sewage treatment works is the "activated sludge" process with separate sludge digestion.

From a study of the first two considerations it will be observed that the seeding of the sewage by this carbohydrate type material is sufficient to convert the sewage into what is veritably a nutrient medium specifically suited to the requirements of filamentous bacteria of the *Sphaerotilus* sp. (The term "carbohydrate" is used to connote carbohydrate degradation products generally, the alcohol fermenting yeasts, and cellulose debris present in the wastes.)

Further, it is generally recognised that the conditions obtaining in a properly operating aeration system tend to favor the growth of filamentous bacteria when sufficient suitable food material is available. At the Glenelg Sewage Treatment Works the substitution of the non-filamentous sludge in the aeration tanks by a development of filamentous material of almost "pure culture" dimensions is complete in one or two weeks after the commencement of winery operations. If the sludge index rises to 500–600, sedimentation cannot be effected in the final separating tanks, and the breakdown of the plant follows. At this stage it might be as well to mention that all the conventional methods of combating such filamentous overgrowth have been tried, such as liming, chlorine, additional aeration, dilution, etc., without really worthwhile results. Approaching the problem from another angle it is apparent that separate treatment of the wastes could be undertaken, either completely, or to a point at which their carbohydrate content would be so reduced as to be incapable of supporting sufficient filamentous growth to impair plant performance. Empirically this has been determined as necessitating a 75 to 80 per cent removal of this carbohydrate content.

Treatment of Wastes

Separate treatment of the wastes at the winery itself was discarded as being impracticable for several reasons.

It was evident that treatment at the winery would lack the necessary expert supervision to achieve best results, as the winery proprietors would, at best, regard the scheme as a necessary evil.

The cost of the treatment plant would also be greater because at the sewage works it is possible to partly utilize units provided for sewage treatment.

Still another consideration influencing the decision to treat the wastes at the sewage works was the fact that the biological filters, which would be used for other purposes during part of the year, would be mature and in good condition at the commencement of the winery season.

The same remarks apply to the sludge digestion tank into which the sludge is pumped.

Having decided that the best place to treat the wastes was at the sewage works, the question of the moment was how to get them there. Obviously it was out of the question on the score of costs to construct a separate pipe line three miles long to the treatment works. The use of the sewer main itself as the separate line, suggested an ingenious

solution to the problem, and after certain trials were made this proposal was adopted. The wastes discharge into approximately one mile of 9 in. and 12 in. tributary sewer before reaching the trunk main, which is at this juncture some 2.25 miles from the sewage treatment works. Tests have shown that the wastes can be stored and discharged from the winery in one flush and delivered to the main pumping station during the early hours of the morning without becoming diluted with more than four or five times their volume of sewage. This sewage-winery waste mix can then be pumped to a section of the sewage treatment works reserved for this purpose, during the low flow period, and given separate treatment. It will not be necessary to effect a clear-cut separation of this waste from all other sewage, as the comparatively small quantity remaining in the main flow will be insufficient to cause trouble in the works.

This utilization of the sewerage system to perform an additional function comparable with that of a separate main, is, as far as it is known, unique, and has been a major factor in deciding the Department to provide treatment for the wastes. The circumstances of this case are no doubt especially favorable towards such an expedient, but there must be many smaller plants throughout the country where a similar scheme could be worked out to facilitate the treatment of such seasonal wastes.

Experimental work has been carried out on this sewage-winery waste mix, which demonstrates that it is amenable to the following combination of chemical and biological treatment:

1. Chemical treatment of the sewage-winery waste mix.
2. Dilution of the resultant supernatant liquor by plant effluent and adjustment of pH.
3. Biological treatment of the diluted supernatant liquor on a two-stage biological filter.
4. Final treatment of the filter effluent in the main plant.

Experimental Plant

The experimental plant consisted of two 15-gal. hopper-bottomed sedimentation tanks, a 13-gal. flocculator with paddles operating at a peripheral speed of 90 ft. per minute, a 60-gal. diluting tank, and a two-stage biological filter. The general construction of the filter may be seen from Figs. 2 and 3. The filter was constructed of 12 in. diameter stoneware pipes, and it consisted of two 6 ft. 6 in. sections. The filter medium used was ¾ in. stone with a 6 in. layer of 1½ to 2 in. stone on top for distribution, and another 6 in. layer of 2 to 3 in. stone for support and drainage at the bottom of each section. This filter was dosed by a tipping bucket elevator, and in small-scale work this method has proved extremely simple and accurate. The bucket elevator was designed to make one revolution per minute and the buckets were checked and calibrated to dose within 0.15 per cent of 60 g.p.d. Change in the

dosing rate or cycle was readily effected by changing buckets and/or speed of drive. This unit has now worked satisfactorily for over a year. Each filter was provided with a hopper-bottomed humus tank giving 2½ hours detention during the winery waste experiment. The effluent from the first stage humus tank gravitated to the second stage bucket elevator compartment, while the second or final stage effluent was pumped to the main plant.

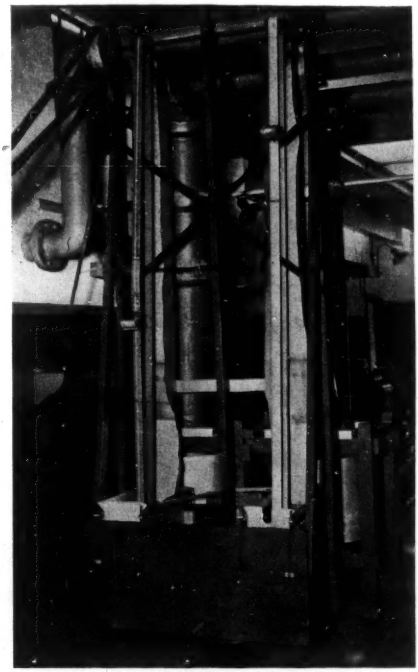


FIG. 2.

Operation.—The biological filter had been treating sewage for six months prior to the commencement of this investigation, and Tables IV, V and VI include results typical of those obtained during this period. The experience gained from other work carried out on this waste in previous years enabled certain conditions and procedure to be adopted from the commencement of the work this season. A schematic diagram of the treatment is given in Fig. 4. Owing to the restricted time available, certain variables were fixed, and the ratio of waste to sewage was maintained at 1 to 5, while the filter dosage rate was fixed

at 76 Imp. gal. per sq. ft. of filter area per day, which is equivalent to an average filter loading of 0.9 lb. of 5-day B.O.D. per cu. yd. of stone. This corresponds to plant scale values of 180,000 Imperial g.p.d. of diluted sewage-winery waste mix with a B.O.D. of 700 p.p.m. In the experimental plant the winery waste was diluted with five volumes of sewage, and then limed. The quantity of lime required was determined

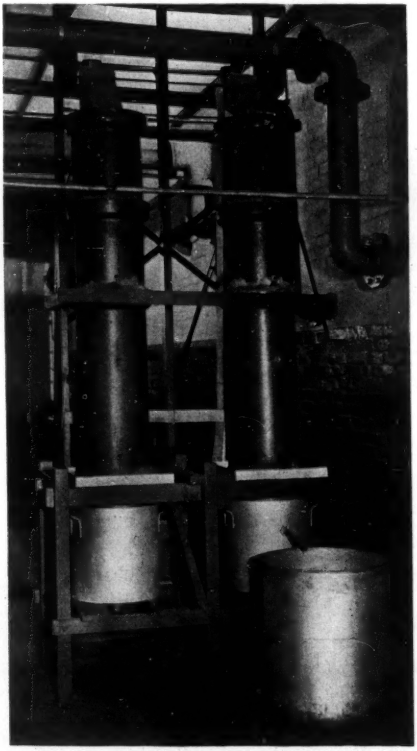


FIG. 3.

on 250–500 ml. of the mix, this procedure taking some ten minutes. The appropriate amount of lime was then mixed up into a slurry and added to the sewage-winery waste mix in the flocculator. The contents were given a rapid mix for about a minute, and then after flocculating for 30 minutes they were drawn off into a hopper-bottomed sedimentation tank. After two hours' settling a good separation of sludge and liquor resulted. The sludge was drawn off, and in plant operation

would be used for adjustment of the acid primary sewage sludge. The clear straw-coloured supernatant liquor was transferred to the filter storage tank and diluted with two volumes of plant effluent. (This is an average figure; the amount depended on the quantity of supernatant

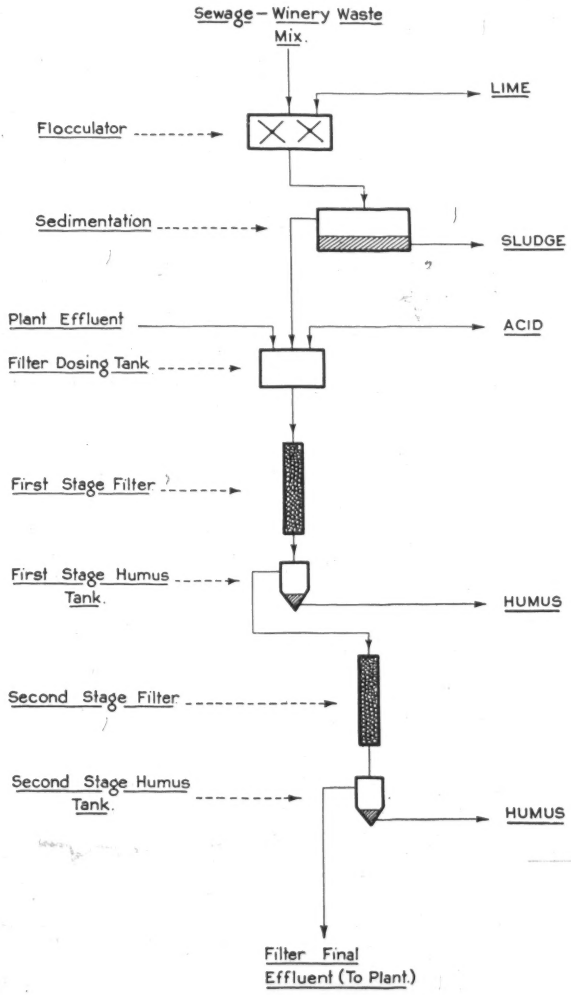


FIG. 4.—Schematic diagram of experimental plant.

TABLE II.—*Results of Chemical Treatment of Sewage-Winery Waste Mix*

Run No.	Period	5-Day B.O.D.			Volatile Matter, Per Cent Redn.	Lime Used, p.p.m. CaO	Sludge from Chemical Treatment		
		Before Treatment, p.p.m	After Treatment, p.p.m.	Per Cent Redn.			Per Cent by Volume	Per Cent Solids	Per Cent V.M.
199–204	March 21–26	2600	2000	23	—	1053	17.5	—	—
206–211	March 28–Apr. 2	2900	1800	38	65.6	1347	16.7	2.51	1.72
213–216	Apr. 4–7	4300	3300	23	52.0	1915	19.7	3.15	1.57
221–225	Apr. 12–16	2300	1400	39	51.6	1356	17.3	2.02	1.20
227–232	Apr. 18–23	2500	1500	40	65.9	926	16.0	2.16	1.28
234–239	Apr. 25–30	2700	1900	30	59.0	1056	14.6	2.43	1.27
241–246	May 2–7	3700	2700	27	56.4	1066	11.0	2.00	1.02
248–253	May 9–14	3400	2100	38	31.2	820	12.0	1.56	0.77
255–260	May 16–21	4600	2600	43	52.7	1120	12.3	2.22	1.12
263–267	May 24–28	4700	2800	40	30.8	1500	16.1	2.32	1.02
269–274	May 30–June 4	—	—	—	56.8	1090	15.8	1.51	0.81
276–279	May 6–9	4600	3300	28	64.2	1375	16.5	2.03	0.95
Average 199–279	Mch. 21/June 9	4200	2700	35.7	55.5	1200	15.0	—	—

TABLE III.—*Chemically Treated Sewage-Winery Waste Mix Applied to the Filter*

Run No.	Period 1939	Chemically Treated Sewage-Winery Waste Mix Applied to the Filter					
		Undiluted, Galls.		Diluted with Filter Effluent			
				Gallons		Reaction	
		Per Day	Per Sq. Ft.	Per Day	Per Sq. Ft.	Acid, p.p.m. H_2SO_4	pH
199–204	Mch. 21–26	9.0	11.4	56	71.3	Nil	10.5
206–211	Mch. 28–Apr. 2	12.0	15.2	60	76.4	600	8.0
213–216	Apr. 4–7	16.0	20.3	60	76.4	1095	7.9
221–225	Apr. 12–16	15.0	19.1	60	76.4	880	7.7
227–232	Apr. 18–23	23.0	29.3	60	76.4	560	8.0
233–239	Apr. 25–30	30.0	38.2	60	76.4	525	7.2
241–246	May 2–7	10.0	12.7	60	76.4	680	7.3
248–253	May 9–14	20.0	25.4	60	76.4	500	7.2
255–260	May 16–21	18.0	22.9	60	76.4	600	7.2
263–267	May 24–28	20.0	25.4	60	76.4	900	8.0
270–274	May 31–June 4	20.0	25.4	60	76.4	580	7.8
276–279	June 6–9	20.0	25.4	60	76.4	700	7.5
Av. 199–279		18.0	22.9	60	76.4	750	7.7

being applied to the filter.) When the experiments were started various chemicals were tried in the chemical treatment of these wastes, viz: $FeCl_3$, $FeSO_4$, etc., but the results obtained were unsatisfactory, and the dosage required (upwards of 400 p.p.m.) was such as to render costs prohibitive, especially in this State with ferric chloride at 6 cents per pound. The quantity of lime required is high (Table II), but drastic alkalinization is necessary, otherwise the resultant sludge is slimy and poor settling. The lime added is, therefore, over and above that necessary to neutralise and precipitate most of the organic acids, etc. present, since there must be sufficient residual alkalinity in the liquor to

TABLE IV.—*Results of Biological Treatment of Diluted Chemically Treated Sewage-Winery Waste Mix*

Period 1939	5-Day B.O.D., p.p.m.			Suspended Solids					
				P.P.M.			Per Cent Reduction		
	Influent to Filter	First Stage Effl.	Final Stage Effl.	Influent to Filter	First Stage Effl.	Final Stage Effl.	Influent to First Stage Effl.	First to Final Stage Effl.	Overall
Pre-winery period. Mch. 15–19. Expt. commenced	120	26	9	130	27	14	79.2	48.1	89.2
Mch. 21–26	435	30	10	91	24	10	73.0	58.3	89.0
Mch. 28–Apr. 2	575	25	14	127	25	14	80.3	44.0	89.0
Apr. 4–7	850	40	15	—	—	—	—	—	—
Apr. 12–16	660	60	37	123	55	21	55.3	61.8	82.9
Apr. 18–23	845	170	100	136	45	22	66.9	51.1	83.8
Apr. 25–30	850	250	100	174	65	31	62.6	52.3	82.2
May 2–7	340	51	30	57	62	27	+ 8.7	56.4	52.6
May 9–14	850	126	60	95	52	29	45.3	79.3	69.5
May 16–21	730	290	60	106	65	35	38.7	46.1	67.0
May 24–28	1050	530	210	96	134	82	+28.3	38.8	14.6
May 30–June 4	680	285	120	80	204	120	+60.8	41.2	+50.0
June 6–9	1010	340	250	104	90	88	13.4	22.2	13.4

coagulate other suspended matter and condition the sludge formed. Under these conditions the final reaction of the liquor is between 10 and 11, even after dilution with two volumes of effluent, and it was noticed that filter slime was apparently being scoured from the surface stones. Adjustment was resorted to by the addition of crude sulfuric acid (S. G. 1.82) to depress the pH to values below 9.0. During the experiment, however, it was evident that filamentous growth was greater between pH 9.0 and 8.0 than between 8.0 and 7.0, and consequently the reaction of the filter influent was generally adjusted to the lower values (Table III). The humus sludge from the filters was drawn off twice per day, and this was made necessary by the high operating temperatures to

TABLE V.—*Removal of 5-Day B.O.D. by the Biological Filter*

Period 1939	5-Day B.O.D.						
	Pounds per 24 Hours per Cubic Yard Stone						
	Applied to Filter	Removed by			Per Cent Reduction		
		First Stage	Final Stage	Overall	Influent to First Stage Effluent	First to Final Stage Effluent	Overall
Pre-winery period. Mch. 15–19. Experiment commenced	0.206	0.160	0.030	0.190	77.7	65.3	92.2
Mch. 21–26	0.748	0.697	0.034	0.731	93.4	66.7	97.7
Mch. 28–Apr. 2	0.988	0.945	0.019	0.964	95.6	44.2	97.6
Apr. 2–7	1.46	1.39	0.043	1.43	95.2	61.4	97.9
Apr. 12–16	1.13	1.03	0.039	1.07	91.1	39.0	94.7
Apr. 18–23	1.45	1.16	0.120	1.28	80.0	41.4	88.3
Apr. 25–30	1.46	1.03	0.258	1.29	70.5	60.0	88.4
May 2–7	0.584	0.496	0.036	0.532	84.9	40.9	91.1
May 9–14	1.46	1.22	0.113	1.33	83.5	47.1	91.1
May 16–21	1.25	0.76	0.395	1.15	60.8	80.6	92.0
May 24–28	1.80	0.89	0.550	1.44	49.4	60.4	80.0
May 31–June 4	1.17	0.68	0.284	0.96	58.1	57.9	82.0
June 4–9	1.73	1.15	0.155	1.30	66.5	26.7	75.1

TABLE VI.—*Nitrogen Determinations on Filter Liquors*

Period	Parts per Million							
	Influent to Filter		First Stage Effluent			Final Effluent		
	Organic	Ammonia	Organic	Ammonia	Oxidized	Organic	Ammonia	Oxidized
Pre-winery period. Mch. 15–19. Expt. commenced	13.2	46.1	3.5	7.3	12.0	2.6	0.2	17.4
Mch. 21–26	12.5	4.5	4.2	1.6	1.8	2.7	0.2	2.6
Mch. 28–Apr. 2	13.8	3.1	4.0	0.2	0.3	2.8	0.1	0.4
Apr. 4–7	—	6.5	—	0.2	—	0.1	—	—
Apr. 12–16	27.2	19.4	10.4	1.0	1.8	6.2	0.7	4.6
Apr. 18–23	64.0	26.8	12.0	3.5	1.1	6.9	1.3	1.0
Apr. 25–30	55.0	28.5	13.3	11.2	0.82	5.4	3.2	1.0
May 2–7	30.1	22.7	9.4	11.0	0.95	10.0	10.8	2.0
May 9–14	28.2	14.8	11.2	3.3	1.6	10.3	4.0	3.1
May 16–21	40.4	13.4	13.6	14.4	0.52	9.4	5.5	0.90
May 24–28	52.5	19.3	13.8	9.3	1.0	13.1	2.9	1.0
May 30–June 4	—	—	—	—	—	—	—	—
June 6–9	66.0	16.4	33.0	11.5	0.6	23.0	7.9	0.4

which the filter was subjected by reason of its being placed in the machinery room. The volume of this sludge was very consistent and averaged 0.5 per cent of the flow throughout the experiment.

The results of chemical treatment are shown in Table III, from which it will be seen that worthwhile reductions in B.O.D. and volatile matter were obtained.

The results obtained by the biological treatment of chemically treated liquor are set out in Tables IV, V, and VI. It should be noted that no wastes were discharged from the winery on Sundays (Mondays on the schedule under which the filter was running), and on this day filter effluent only was re-circulated.

It was realised that the loading proposed would be heavy. However, knowing that a filter in good condition will stand up to heavy overloads for a short period, it was argued that the filter would operate satisfactorily during the first three or four weeks, which represents the peak of the winery season. After this period the quantity of waste decreases somewhat, and it was felt that the filter could continue to handle the reduced loading, probably without any deterioration of the effluent. In the experimental work, however, the loading was kept up to that of the peak period throughout, and it is evident that towards the latter part of the experimental period (from May 28th) the loading is much higher than would be experienced in practice. During the latter period the volume of wastes would not exceed 4,000 Imp. g.p.d., whereas they were rated at 12,000 Imp. g.p.d. in the filter experiment. Under these conditions it is not surprising that the filter broke down.

Filter performance was held to be satisfactory if the B.O.D. of the final effluent did not exceed 60 to 80 p.p.m.

From Table IV it will be observed that this condition held during the first month of operation, and that the first departure from this standard occurred during the fifth week, apparently due to the cumulative effects of heavy loadings. The filter recovered quickly over the period of light Sunday loading, but broke down again at the end of the week's run. The loading was somewhat reduced (Table III, Runs 241–246) and filter performance was again up to the standard set. On May 15th the filter order was reversed as No. 1 filter surface showed signs of clogging, though the liquor was still getting away freely enough. It was at once apparent that the second-stage filter was not built up sufficiently to cope with the heavy initial load, and though the filter order was restored 14 days later, filter performance did not recover. The experiment may, therefore, be regarded as concluding at run 267 (May 28th).

Filter Life.—No detailed investigation of filter life was made. At the commencement of the experiment the filter slime presented the appearance of a typical filter sludge of high purifying capacity, viz: large discrete flocculent masses of rich brown material and zoogloea with a practical absence of filamentous forms. The unloaded material settled rapidly in the humus tanks, being black from the first stage filter when the sewage was being dosed with iron salts, and rich brown from the

second-stage unit. The protozoa present were relatively few in number and confined to the usual assemblage of paramecium, minute ciliates, aspidiscus and small colonies of peritrichs. The most abundant protozoön was the arcellidae, whose tests were inky black in the first stage sludge and colored by ferric iron compounds in the second. Larger organisms present consisted of rotifers, tubifix and nematode worms, and a great variety of mites, bugs, daphnia, cyclops and water spiders.

On the surface of the filters psychoda were noted, but never in great numbers, and a swarming development of springtails occurred during the experiment.

After a fortnight of operation with the winery waste liquors the filter slime was converted into a felted mass of filamentous material, and the larger aquatic forms of life died rapidly, followed later by most of the protozoa, though arcella remained throughout the whole experiment. This has also been noted in the sludge from the aeration tanks of the large plant. While the wastes were being treated on the filter, nematodes increased rapidly, but otherwise there was little change in the sludge during the experiment.

The Treatment Plant

Having proved experimentally that the waste could be treated by the methods proposed to a degree that would allow of it being given final treatment with the sewage, and having demonstrated by actual trials that it could be brought to the works by way of the sewerage system in the early hours of the morning, and that there was no appreciable difficulty in separating it from the sewage, it was decided to proceed with the design of a plant to treat the wastes concurrently with designs which were being prepared for extensions to the sewage treatment works.

It soon became evident that it would be uneconomical to build a plant specially for treating these wastes and to have it standing idle for about half the year, consequently it was decided to utilize, as far as possible, units which could be used for other purposes, either during the period of light winery waste discharge or during the period of no waste discharge.

In order to make the following remarks understandable it is necessary that the proposals for the treatment of the sewage be briefly explained.

The preliminary treatment consists of screening and mechanical flocculation, followed by sedimentation in "straight-line" type settling tanks. Provision has been made for adding chemicals for a few hours of the day on several days of the week to reduce peak loading to the biological treatment units, and a chemical dosing plant has been provided, also a "Flash" or Turbo type mixer to enable this to be done.

For secondary treatment the activated sludge process is employed. Sludge is to be digested in two-stage digestion tanks and the digested sludge dewatered on sand drying beds. During the wet winter months

when drying is at a minimum, the surplus sludge over and above that which can be dried on the beds is to be dewatered on vacuum filters. Prior to vacuum filtration the sludge will be elutriated.

Another aspect of the situation which has a bearing on the possible use of sewage treatment units for handling the winery wastes is that the usual period of maximum wet weather flow does not coincide with that of peak winery activity. Likewise the period when filtrate and elutriate from the sludge dewatering plant have to be treated does not coincide with this period.

It was decided, therefore, to so design the flocculation and sedimentation units as to allow one section to be withdrawn from service for the chemical treatment of the winery wastes. With such an arrangement the chemical treatment of the wastes can be carried out without the provision of any additional tanks or equipment, while the sludge can be handled by the same equipment as is used for handling the sewage sludge, and pumped direct to the sludge digestion tanks.

In the case of the secondary treatment units, experimental work showed that a two-stage biological filter designed to treat the peak winery waste flows will treat comfortably all digestion tank supernatant and sludge filtrate and elutriate from the plant. Consequently it was decided to treat these wastes on the biological filter during the whole of the year except during the two months of peak winery waste discharge. During these two months the only other waste to be treated is the digestion tanks supernatant, and this it is proposed to settle and then bleed at a uniform rate direct to the aeration tanks. This method of treating digester supernatant has proved very successful at our Port Adelaide plant.

Basis of Design.—Based on the experimental and trial work carried out, the following figures were accepted as the basis of the design:

1. Volume of undiluted winery wastes—12,000 Imp. gal. per day.
2. Volume of winery waste-sewage mixture diverted at the works for separate treatment—60,000 Imp. gal. per day.
3. Rate at which the winery waste sewage mixture will be received at the works—800 Imp. gal. per minute.
4. Time over which winery waste sewage mixture will be received at the works—75 minutes.
5. Quantity of lime to be added for chemical treatment—720 lb. per day (average).
6. Volume of chemically precipitated sludge—8,000 Imp. gal. per day.
7. Volume of diluted chemically treated waste for application to the biological filters—180,000 Imp. gal. per day.
8. 5-Day biochemical oxygen demand of diluted chemically treated waste—700 p.p.m.
9. 5-day B.O.D. in diluted chemically treated waste to be applied to filter daily—1,260 lb.

Chemical Treatment.—The design provides for the winery waste-sewage mixture as it arrives at the treatment plant to be first passed

through the bar screens as provided on the main influent to the sewage treatment plant, after which the requisite amount of lime is added to it by means of two chemical dry feeders, each capable of a maximum output of 500 lb. of lime per hour. The waste and added lime will then be rapidly mixed together for a period of about 30 seconds by means of a "Flash" mixer, after which it will be diverted to a section of the flocculation tank which has been withdrawn from normal service for this purpose.

The section of the flocculation tank used for this purpose is rectangular in plan, 26 ft. long, 16 ft. wide, with an average water depth of 9 ft. and has a capacity equal to approximately 30 minutes of winery waste-sewage flow.

During its passage through this unit, the waste with the added lime is gently stirred. The stirring is accomplished by mechanical paddles chain-driven by an electric motor operating through reduction gearing, the peripheral speed of the paddles being variable but averaging 90 ft. per minute.

From the flocculation tank the liquid is passed without undue disturbance to a "straight line" type sedimentation tank, which has likewise been withdrawn from normal service for this purpose and which has sufficient capacity to hold at least one day's flow of flocculated waste.

This particular unit is 95 ft. 9 in. long, 16 ft. wide, with an average water depth of 10 ft. 10 in., and so it will be seen that it has capacity to spare when used for this purpose. It is equipped with "straight line" type sludge collector equipment, and a cross-collector at the sludge withdrawal end.

The mixture will be allowed to stand quiescent in this unit during the whole of the day, and during this period the flocculated solids are expected to settle to the bottom, from where they will be collected and periodically pumped to the sludge digestion tanks. A Duplex plunger type pump is provided for this purpose. A special decanting device, which has been designed to withdraw supernatant liquor at a uniform rate over the 24 hours, has been provided at the outlet end of the tank, and by this means supernatant liquor will be withdrawn throughout the day to a small pump sump nearby. Sufficient liquor will be withdrawn from this tank during the 24 hours to make room for the next day's flow of sewage-winery waste mix.

Because of the high temperatures prevailing during the summer months and the concentrated nature of the sewage, preliminary treatment is inseparable from some odor nuisance, and as the plant is located near a fashionable beach, it has been deemed advisable to enclose the screen house and to cover the flocculation and sedimentation tanks with a flat slab roof. This fits in very well with the treatment of the winery wastes, as our experimental work has shown that this treatment is accompanied by a certain amount of odor.

This then introduces the question of the ventilation of these units, and this has been attended to by so arranging the plant that the air

compressors used in the activated sludge process draw their free air through these units.

Biological Treatment.—As pointed out above, the supernatant from the chemically treated sewage-winery waste mix is decanted off at a uniform rate of the suction pit of a small pumping station. Here it is continually diluted with about two volumes of plant effluent, after which sufficient sulfuric acid is added to adjust its pH to slightly under 8.0. The H_2SO_4 will be dosed continuously at the desired rate by means of an "Omega" type liquid chemical feeder.

Small two-speed centrifugal pumps have been provided for elevating this liquor to the biological filters, and these have capacities of 150 and 100 Imp. gal. per minute at high and low speed respectively.

Biological Treatment Units.—The units comprising this section of the treatment plant consist of two biological filters operating in series, each 60 ft. in diameter, with a 6 ft. 6 in. depth of filter bed. This filter bed will be made up of 1 ft. of 1½ in. to 2½ in. stone on top, beneath which is 5 ft. of ¾ in. to 1½ in. stone, and on the bottom 1 ft. of 2 in. to 3 in. stone. This stone is supported by a specially designed underdrainage system. The liquor will be applied to these filters by revolving type distributors, which in turn are driven by water wheels actuated by the falling liquid. The distributors will be of the two-arm type, one arm only coming into operation for the smaller flows, while both arms will be utilized for distribution with the larger flow.

Because of the odors associated with the application and treatment of these wastes, and also that of the digestion tank supernatant, it was decided to cover the filters and employ artificial ventilation, a high pressure fan capable of supplying up to 1,000 cu. ft. of free air per minute at 2 in. water gauge being provided for each filter, and located in the filter roof. This represents a maximum possible air supply of 2,100 cu. ft. of free air per cu. yd. of filter medium per day, or 8 cu. ft. per Imp. gal. of liquid applied to the filter. Provision has been made for reducing this quantity if found desirable.

It is expected that the covering of the filters will completely eliminate fly nuisance as well.

The size of these units was determined on the basis of the following peak loadings:

(*a*) 0.93 lb. of 5-day B.O.D. per cu. yd. of filter medium per day.
(*b*) 132 Imp. gal. of liquid per cu. yd. of filter medium per day.
(*c*) 573 Imp. gal. of liquid per sq. yd. of filter per day.

Based on ordinary standards this is very heavy loading. However, the experimental work has shown that such loadings are possible for a period at least equal to that of the peak winery waste discharge.

The necessary "light" openings have been provided in walls and roofs, as have the necessary access facilities. As pointed out above these two filters are arranged for series operation. However, the pipe work has been so arranged that either filter may be made the leading unit, and so, if necessary, tendencies towards filter choking in the leading filter may be combated. Figure 5 shows a cross-section of one of the filter units.

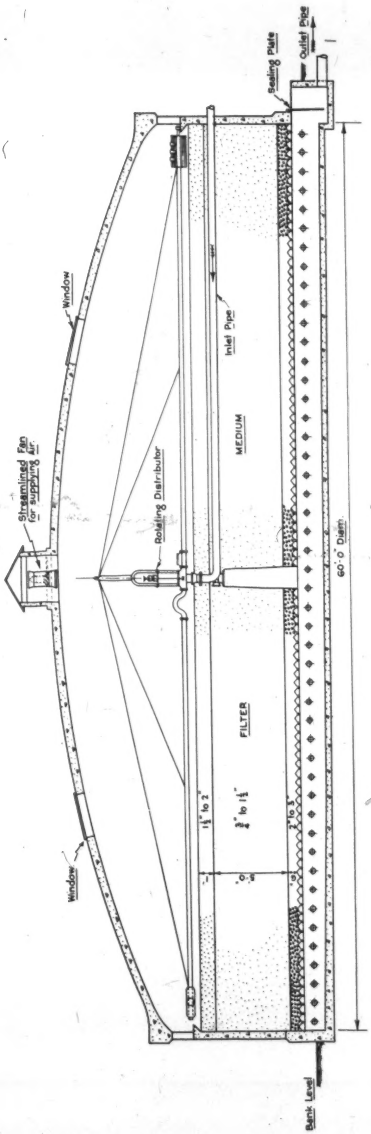


FIG. 5.—Biological filter.

Humus Tank.—In the experimental work a humus tank was used after each filter stage. However, our experience with this work demonstrated that the work performed by the second tank was insufficient to justify its use, particularly in view of the fact that the effluent is to be given further treatment in the treatment plant proper. Consequently only one humus tank is provided in the design and it is so arranged that it can be used after either filter, depending on which is the leader.

The humus tank provided in the design is of the true Dortmund type with a Clifford type inlet. It is 20 ft. square on plan, has a side water

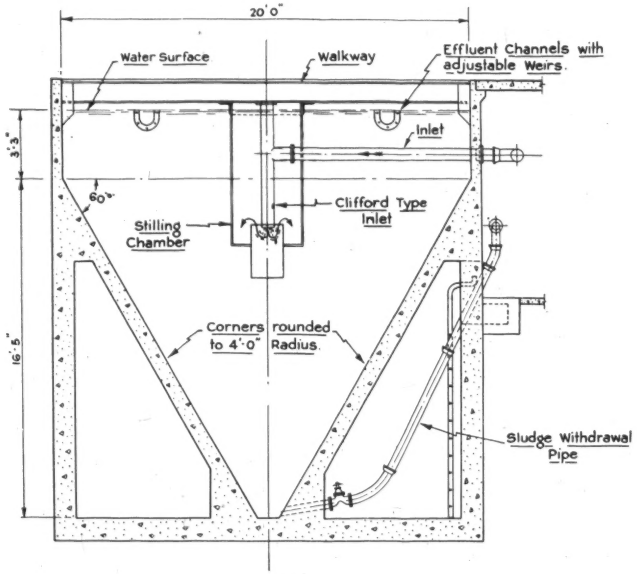


FIG. 6.—Cross section of humus tank.

depth of 3 ft. 3 in. and a hopper bottom with sides sloping at 60° to the horizontal, giving a total water depth of 19 ft. 8 in. and a capacity equal to 2½ hours of flow. The corners of the hopper are rounded to a radius of 4 ft. and the sludge withdrawal pipe is placed outside the tank, both features being designed to remove possible obstructions to sludge settling.

The central baffle chamber is in steel, as are also the effluent collection troughs which are located midway between the outer walls of the tank and the stilling chamber. The weirs are of steel and adjustable. A cross-section of the humus tank is shown in Fig. 6.

The humus sludge, which based on the results of the experimental work will have a volume equal to about 540 Imp. gal. per day, will be withdrawn and pumped direct to the sludge digestion tanks.

The supernatant from the humus tank will be pumped to the second-stage biological filter, which is identical in all respects to the first-stage filter.

The filtrate, which is collected from the second-stage filter unit, is the final effluent of the plant, and it will be passed direct to the aeration tanks for final treatment with the sewage.

Construction Program

As the main sewage treatment plant will have capacity to spare during the early years of the design period, it is evident that less treatment of the winery wastes will be necessary during this period, and so it was decided to build one of the biological filters and the humus tank for the time being, leaving the construction of the second unit until it is required.

It is believed that the single stage biological unit will reduce the carbohydrate content of the waste sufficiently to prevent it causing sludge "bulking" troubles in the aeration tanks during the early years when these tanks have reserve capacity. This belief is supported by the results obtained from the experimental plant.

Costs

The question of costs does not enter into the subject matter of this paper. However, as a matter of interest the following is submitted:

The cost of lime locally is £3.6 per ton, while sulfuric acid (S. G. 1.82) costs £9.33 per ton.

Based on the use of 850 lb. of lime (85 per cent CaO) and 400 lb. of acid per day, the cost of treatment of 60,000 Imp. gal. of sewage-winery waste mix is £3.3 per day, or £198 a year based on a winery season proper extending over 60 days each year.

No additional labor is required, and the cost of electrical energy is small as it is generated at the plant using sludge gas as a fuel.

Summary

Experimental work carried out during two winery seasons demonstrated that winery wastes mixed with sewage in the ratio of 1 to 5 could be successfully treated by chemical treatment using excess quantities of lime, followed by dilution and pH adjustment, with subsequent treatment on two-stage biological filters.

The effluent obtained was such that it could be returned to the plant for further treatment with the sewage without any risk of upsetting that plant.

A full-scale plant was then designed, embodying the features proved satisfactory in the experimental work.

Acknowledgments

The Ministerial Head of the Engineering and Water Supply Department is the Hon. M. McIntosh, while Mr. H. T. M. Angwin is Engineer in Chief, and Mr. J. W. Murrell, Engineer for Sewerage.

Operators' Reports and Suggestions

W. D. HATFIELD

249 Linden Place, Decatur, Ill.

NOTES ON THE "COST OF SLUDGE DISPOSAL" SYMPOSIUM *

BY J. W. KIRKPATRICK

Asst. Engineer, Bureau of Sanitary Engineering, Indiana State Board of Health

At the combined meeting of the Indiana Sewage Works Association in Indianapolis, papers from Goshen, Kokomo, LaPorte, Michigan City, Richmond and Salem were presented and discussed. To a few of those present, the symposium showed some indications of being worth the effort spent in preparation. To others present, the affair apparently was a lot of words, numbers and paragraphs.

The various writers were not in agreement as to what form and nomenclature were in order in reporting the cost of sludge disposal. Burrin † of Kokomo just about summarized the difficulty when he said, "This association should set up a standardization of costs entering into the handling of sludge . . . and give each plant something to shoot at in compiling costs. In the cost of handling sludge, shall we consider the costs of digesters, interconnecting piping, building allocation, etc.? I raise these questions to get a better understanding of what we are going to include in what we go after. We will be only too glad to obtain material for a study of this type if we can agree on what information shall be obtained."

Jones,‡ reporting on the cost of sludge disposal at Michigan City, presented an interesting paper, the highlights of which are as follows:

"The Michigan City Sewage Treatment Plant is designed and operated for complete treatment of a 'combined' sewage and embodies the following features in that treatment: grit channels, bar screens and screenings grinder, plain sedimentation tanks with straight line skimmers and sludge collectors, separate sludge digestion tanks followed by drying beds and lagoons.

The secondary plant consists of spiral flow aeration tanks followed by circular sedimentation and clarifying tanks.

Surplus activated sludge is wasted to the sewage ahead of the plain sedimentation tanks and is settled out in the primary system with the settleable solids in the raw sewage. This mixture is pumped to the sludge digestion tanks as raw sludge. Ripe sludge from the digestion tanks is discharged by gravity onto underdrained gravel and sand

* From "Sewage Gas," Indiana State Board of Health, B. A. Poole, *Chf. Eng.*, Paul Kleiser, *Editor.*

† T. J. Burrin, Superintendent of the Kokomo Sewage Treatment Plant.

‡ H. H. Jones, Superintendent of the Michigan City Sewage Treatment Plant.

filled drying beds or to lagoons as the occasion demands. When the plant was designed glass covers were specified for the drying beds but lack of funds necessitated their omission. In consequence, the area of the beds proved inadequate and lagooning of ripe sludge was resorted to.

The digesters have a combined capacity of 146,000 cu. ft. or a design capacity of 3 cu. ft. per capita. There are three of these. One, having a floating cover, is used as a primary digester and the two having fixed covers, as secondary digesters or storage tanks. Gas generated in the digesters is used in an internal combustion engine.

The sludge drying beds are three in number. Each is 50 ft. wide by 150 ft. long. The combined area is 22,500 sq. ft. or ± .5 sq. ft. per capita, design basis.

During the first year of operation these beds were filled to a depth of 12 in., but during the second and third years this was reduced to 10 in. with negligible results in time saving so far as could be observed. The weather seems to be the deciding factor.

The plant commenced primary operation on May 1, 1936, but it was not until almost January 1, 1937, when ripe sludge was discharged to the drying beds. At this time there was approximately 150 'dry tons' of suspended solids in the digesters. Subsequent samplings reveal that this 150 tons seems to be the right 'working balance.'

In this discussion the *unit* taken is the *dry ton* of suspended matter discharged from the digester to the drying bed. This unit is chosen for the following reasons: it represents the ultimate end-product; it is possible to determine it accurately; it is possible to determine it with reasonable accuracy using crude equipment; and it eliminates uncertainty of volume due to moisture content of dry sludge.

The period embraced is from January 1, 1937 to August 31, 1939. During the 32 months under consideration:

86 batches or 1,113 dry tons, having a wet volume of 571,000 cu. ft. were drawn from the digesters. Of these 86 batches:

54 batches, or 777 dry tons, having a wet volume of 366,000 cu. ft. were delivered to drying beds, and

32 batches or 336 dry tons, having a wet volume of 205,000 cu. ft. were delivered to lagoons.

In physical character the sludge 'to beds' averaged 7 per cent suspended solids and 93 per cent moisture and the sludge 'to lagoons' averaged 5.9 per cent suspended solids and 94.1 per cent moisture.

Cost of Delivering Sludge from Digesters to Beds.

270 hrs. operator's time @ 60¢	$ 162.00
270 hrs. asst. operator's time @ 55¢	148.50
216 hrs. helper time (reconditioning) @ 50¢	108.00
Total	$ 418.50
Plus 25 per cent for superintendence and technical	104.62
Total direct labor	$ 523.12
Cost for maintaining drying beds:	
300 tons washed torpedo sand	$ 374.38
Truck hire hauling sand to beds	81.00
Labor unloading and spreading sand	219.00
Total cost of maintaining beds	$ 674.38
Total direct cost for 777 dry tons sludge delivered to drying beds	$1,197.50
Total direct cost for 1 dry ton to drying beds	1.541

Cost of Delivering Sludge to Lagoons. Three lagoons for storing ripe sludge were built but since only two are in use the cost of two lagoons, only, will be considered. In

constructing these lagoons it was necessary to build 450 lineal feet of dam 5 ft. high by 4 ft. wide on top and 19 ft. wide at the base. The yardage involved was 960 cu. yd. The capacity of the two lagoons is 100,000 cu. ft. While there has been discharged to these lagoons 205,000 cu. ft. of wet sludge they are only half full so in figuring cost of lagooning sludge only half the cost of the dam will be considered:

Three lagoons for storing ripe sludge were built but since only two are in use the cost of two lagoons, only, will be considered. In constructing these lagoons it was necessary to build 450 lineal feet of dam 5 ft. high by 4 ft. wide on top and 19 ft. wide at the base. The yardage involved was 960 cu. yd. The capacity of the two lagoons is 100,000 cu. ft. While there has been discharged to these lagoons 205,000 cu. ft. of wet sludge they are only half full so in figuring cost of lagooning sludge only half the cost of the dam will be considered:

160 hrs. operator time @ 60¢	$ 96.00
160 hrs. asst. operator time @ 55¢	88.00
Total	$ 184.00
Plus 25 per cent for superintendence and technical	46.00
Total direct labor	$ 230.00
½ cost of constructing dam	240.00
Total direct cost of delivering 336 dry tons to lagoon	$ 470.00
Total direct cost of delivering 1 dry ton to lagoon	1.339
Aggregate cost for delivery of 1,113 dry tons to beds and lagoons:	
Cost of sludge to beds	1,197.50
Cost of sludge to lagoons	470.00
Total cost	$1,667.50
Average cost for 1 dry ton to beds or lagoons	1.498

Some revenue has accrued from sale of sludge. To date this has amounted to $587.85. If this amount is deducted from the aggregate cost of sludge delivery to beds and lagoons the result is the net cost of sludge delivery, or $1,079.65 or $0.969 per dry ton of sludge.

Since it has never been necessary, at Michigan City, to unload a sludge bed or dig out a lagoon of sludge, the direct cost for sludge disposal stops at this point. However, a few observations and equivalents may help operators of other plants make comparisons:

Minimum 11–2 yd. loads or 22 cu. yd.
Maximum 23–2 yd. loads or 46 cu. yd.
Average 18–2 yd. loads or 36 cu. yd.

Since the total dry tonnage of 54 beds was 777 dry tons it follows that the average bed contains 14.4 dry tons, and

1 dry ton = 2.5 cu. yds.
or 1 cu. yd. = .4 dry ton or 800 dry pounds.

On a cubic yard basis, assuming the above to be correct, the net cost of handling the average cubic yard from digester to bed at Michigan City would be .4 × $0.969 or $0.388.

It is of passing interest to note that 1,113 dry tons is the end product of 4,500 million gallons of sewage entering the plant. This is the equivalent of .244 dry tons or 488 dry pounds per million gallons.

For those interested in non-operating costs at this plant the following may be of interest: The Department is capitalized at $825,134.82, made up in the following grouping:

Collecting system (interceptors, sewer, etc.)	$410,392.47
Treatment plant and equipment	401,395.00
Land	13,347.35
Total	$825,134.82

This represents revenue bonds, moneys donated by P.W.A. and materials and labor donated by W.P.A.

During the period embraced in this report, payment on debt retirement and interest for that part of the capitalization representing sludge beds was $1,002.90. If this amount was chargeable to operation the cost per dry ton for handling sludge would be increased by $0.901."

Other papers indicated that similar treatment plants are likely to arrive at similar sludge disposal costs. Ross,* of Richmond, reported a disposal cost per cubic yard of dried sludge ranging from $.324 to $.634 which appears to agree with Michigan City's costs. Reports on incineration costs at LaPorte and Kokomo showed that the unit costs were higher and that the charges per dry ton of sludge incinerated decrease rapidly as the length of incinerator runs increases.

Another interesting item brought out in this symposium was the wide variation of experience in regard to the removal of dried sludge from drying beds. In some localities, there is a sufficient demand for the sludge to allow some revenue to accumulate from its sale. Some plants must give the sludge away to facilitate its removal from the beds while a few plants find it necessary to use their own resources in removing and disposing of the dried sludge. Offhand, it appears that the demand for dried sludge for agricultural purposes could probably be increased somewhat in most communities by a little advertising.

In order to get an opinion into the records and in order to start a discussion of the subject, this writer proposes that sludge disposal costs be computed as follows:

1. The total cost of sludge disposal shall be the sum of the following items minus the credits accrued from gas power utilization in other processes, and from the sale of sludge.

A. Fixed charges on all portions of the capitalization (structures, land, piping, pumps and other equipment), representing sludge control, handling and disposal facilities. Depreciation should be included.

B. Maintenance charges on all of above facilities (materials and labor).

C. Operation charges on all of the above facilities (materials, labor, power and heat).

Note.—Labor includes common labor, technical control and supervision. It is assumed that sludge handling equipment consists of piping, digesters, gas storage tanks, drying beds, incinerators, and all other facilities which would not be present if sludge had the habit of mysteriously disappearing at the end of the sedimentation (or digestion) process.

* W. E. Ross, Superintendent of the Richmond Sewage Treatment Plant.

Editor's Note.—It is debatable if depreciation should be included. Also the record of the items *A*, *B*, and *C* above should be kept as separate items in order that satisfactory comparisons may be made with other treatment plants.

OPERATION RECORDS AND WHAT THEY MEAN

By Kenneth Morkert

Supt., Dept. of Sanitation, Frankfort, Indiana

Why go through the daily routine of filling out long tedious operation record forms? This is a question which we all ask ourselves at some time or another. These records, however, are of vital importance to our well being. I would like to outline here five major reasons for the keeping of operation records. They are:

(*a*) To provide protective proof if and when law suits arise regarding alleged poor operation of our plants.
(*b*) To provide suitable data for the design of extensions to our plants.
(*c*) To indicate whether our plants are functioning properly.
(*d*) To allow us to sum up just what we have accomplished.
(*e*) To provide authentic data for our monthly and yearly reports.

To the small plant operator who has no laboratory to assist him in obtaining technical data, no flow meters or other recording devices, the matter of records may seem of small consequence. He must remember, however, that each day he performs certain duties in a routine manner. These duties, if properly recorded, form a valuable source of information to him at a later date when compared with the actual accomplishments of his plant. For instance, there may be a short period of time during the year that he is bothered with certain difficulties. In looking back over his records he finds that these same difficulties occurred at approximately the same time of the year under the same operating conditions. This would tend to show the necessity of changing his operating schedule during that time of the year to meet that particular condition. The operator might want to know the amount of screenings taken off the bar screens in order to show his superiors that a mechanically raked bar screen would pay for itself in the amount of labor saved and would be more positive in its accomplishments. He might also wish to make a little money on the sale of sludge to help appease the unhappy taxpayer who just cannot understand why a sewage treatment plant needs so much money to operate on. This would again bring him back to his records. Just how much sludge does the plant produce in the course of a year and is there enough to warrant the buying of equipment to process this sludge.

These questions and hundreds of similar questions may be answered for the operator who sees the value of keeping these records and using

them after they are once made. This brings to mind another thought —that of the operator who records all of his data and various findings but who fails to profit from these recordings. Don't make the mistake of keeping records to collect dust in your files. If you do this, you are as much at fault as the operator who keeps no records at all.

A great deal more can be said about this subject of operation records than I could ever hope to report here. I believe that if you will just go back to those five major reasons for keeping records that I set forth at the very beginning of this paper and analyze each one separately you will prove to yourself the value of operation records.

SPRING MILL STATE PARK HOTEL SEWAGE TREATMENT PLANT

By R. W. Heider

Asst. Engineer, Bureau of Sanitary Engineering, Indiana State Board of Health

A mechanical aeration-activated sludge type sewage treatment plant was completed at Spring Mill State Park in March, 1939. This plant was constructed to treat the sewage from the new park hotel and adjacent cabins. This project is part of the program of the State Conservation Department to improve the sanitary facilities at the state parks and thus protect the health of the million or more persons that visit these recreational areas annually.

The plant was designed to treat 25,000 gals. of sewage per day with a maximum rate of flow of 40,000 gals. per day. During the months of warm weather, the average population of the hotel is from 100 to 150, including employees. On week-ends the population is about 400. The hotel operates its own laundry. At the present time the capacity of the plant is considerably greater than necessary.

Description of Plant.—A sanitary sewerage system collects the sewage from the hotel and cabins and conveys it by gravity flow through an 8 in. sewer to the treatment plant located in a nearby wooded ravine. Although the plant is within 200 yds. of the hotel, the wooded ravine provides a suitable isolated site.

The sewage is discharged into a small by-pass chamber and thence through a 7 in. comminutor to the primary settling tank. The comminutor reduces the large pieces of matter in the sewage to small particles so that they will not clog any conduits and eliminates the handling of screenings. The comminutor can be by-passed and the sewage discharged directly to the primary tank. All flow through the plant is by gravity.

All the treatment units except the sludge drying beds are an integral part of one compact concrete structure. These units are the comminutor, primary settling tank, combination aerator-clarifier, waste sludge hopper, digester and control room.

The primary settling tank is a rectangular hopper bottom tank equipped with a scum trough which drains the scum to the digester. Sludge collects in the hopper bottom and is drawn to the digester by gravity. The sloping sides of the tank are scraped down with a long handled squeegee before sludge is drawn. The tank is 6 ft. wide and 10 ft. long and has a liquid depth of 10 ft.

The settled sewage flows into the aeration tank of the combination aerator-clarifier. This unit is 13 ft. square with a liquid depth of 10 ft. The bottom slopes to the center. The aeration volume is that between the outside tank walls and the 8 ft. diameter galvanized iron settling chamber at the center. The settling chamber surrounds the draft tube and aerator propeller. Directly above the propeller is the diffuser cone which directs the sewage out into the air and thence onto the splash plates above the settling chamber. The primary effluent flows into the aerator, is mixed with the mixed liquor, and is circulated and aerated continuously. The sewage is pumped up the draft tube by the propeller near the top of the tube and is forced against the diffuser cone. Mixed liquor continuously flows from the aeration section to the clarifier compartment.

A waste sludge hopper adjacent to the aeration tank is used to control the sludge content of the mixed liquor. This hopper is 4 ft. square with a liquid depth of 5 ft. It is connected to the aeration tank by two openings. One opening, the inlet, is equipped with a gate and the other, the outlet, is equipped with an adjustable weir. By adjusting the inlet and outlet, the flow of mixed liquor through the hopper is controlled. Waste sludge which settles to the bottom of the hopper is drawn by gravity to the digester.

As was previously mentioned, mixed liquor flows continuously from the aeration section to the secondary settling or clarifier section. The clarifier is cylindrical in shape with a conical bottom. The upper part is 8 feet in diameter and the lower part is reduced to a diameter of three feet. The sewage entering the clarifier must flow upward and over the circular weir located around the draft tube underneath the cover of the clarifier compartment. Sludge which settles out of the clarified liquid drops down into the conical portion of the clarifier and is discharged into the stream of mixed liquor entering the lower end of the aerator draft tube.

Sludge is drawn from the primary tank and waste sludge hopper to the digester by gravity. The digester is of the fixed cover type and is 13 feet square with a liquid depth of 11.5 feet. There are no provisions for heating the sludge.

There are two sludge drying beds of the conventional design. Each is 10 by 20 ft. making a total of 400 sq. ft. drying area. The under drains discharge to the outfall sewer.

Remarks.—All construction work on this sewage treatment plant was done with Civilian Conservation Corps labor. The material and equipment cost was approximately $4,500.

SEWAGE DISPOSAL PLANT FOR TEMPE, ARIZONA*

By E. W. Daley

City Manager

The construction of an adequate sewage disposal plant for the city of Tempe has long been one of the major problems confronting this city.

The original estimate of the cost of the project was $65,000. The low bid was accepted at $51,444. With the addition of a number of extras, the original estimate of $65,000 was the eventual cost of the plant. A grant of $29,250 was made by the P.W.A., plus a loan of $35,750 to be repaid by means of sewer rental. A sewer rental ordinance was passed by the city council.

The schedule of charges applied to the sewer rental ordinance is on a flat monthly charge, based on the size of the meter that furnishes domestic water to the consumer. This charge is not made to the property owner necessarily, but to the actual user of sewer service.

The type, size, and location of the plant was decided after a careful study of the recommendations of the engineering firm of Hawley, Freese, and Nichols of Ft. Worth, Texas. This firm was employed in 1937 to make a survey of the sewerage system of the city, and submit a design that would meet the approval of the Engineering Division of the Arizona State Board of Health. The city asked that this proposed plant should be capable of expansion as the growth of the city demanded it.

The location of the plant that was finally agreed upon, is one that will allow the sewage to enter and leave the plant, without the necessity of pumping. The plant consists of an Imhoff Tank 22 by 77 ft. by 19 ft. depth, a sand trap, bar screens, three Dunbar beds, and the necessary sludge drying beds to receive the sludge produced by the Imhoff Tank.

The location of the plant is ideal from the standpoint of economy, but developed several difficulties in its construction. First, the soft silty texture of the soil necessitated an extra large excavation for the construction of forms for the Imhoff Tank. Second, the Imhoff Tank required depth placed the bottom of the excavation below the standing water level. Third, the removal of the excavation water to permit the fabrication of the tank bottom taxed the resources of the contractor.

The location of the plant placed an extra burden of expense on the city, for it was necessary to build a levee around the entire plant to remove the hazard of floods. Inasmuch as the plant is placed on the south bank of the Salt River, at a point sometimes reached by the river in flood stage, this levee had to be properly placed and constructed so that it would not scour, and would preclude the entrance of any flood waters.

An item that made the construction of the plant difficult was the scarcity of some grades of gravel used in the construction of the Dunbar

* From "Official Bulletin," Arizona Sewage and Water Wks. Assn., Jan., 1940.

Beds. These Dunbar Beds are 112 ft. long and 110 ft. wide, filled to a depth of 4 ft. with sand and gravel, with an additional 1 ft. of freeboard. The floor and sloping sides of these beds are of reinforced concrete. The floors of each bed are pitched to drain to three troughs running lengthwise of the bed. These troughs are roofed with concrete slabs slotted to permit the filtrate entering the troughs, and so constructed as to prevent the exit of filter materials.

The bottom of the bed is covered to a depth of 20 in. with river boulders, 3 to 6 in. in size. On top of this base course, an 8 in. layer of 1 to 1½ in. rock is placed, followed by a 6 in. layer of ¼ in. gravel. The actual filtering medium is the 16 in. depth of sand ½₅ to ⅛ in. placed over the preceding layers. The surfaces of these filters are regularly hand cleaned, whenever it is apparent that clogging is taking place.

The Imhoff tank effluent is distributed over the surface of these beds by three wooden troughs in each unit. These troughs are laid on the surface of the sand and, due to the construction, permit a ready adjustment of flow over the entire surface. After passage through the beds, the effluent is piped to the river. Each bed is a separate unit. One is used for 10 days, is allowed to dry out, the top is raked, and it is then put back into service.

Grass, trees, shrubs have been planted on the levees to insure the stability of these dikes. The city feels that they have accomplished a great deal in converting what was formerly a cesspool in the midst of a jungle, to a clean, healthy locality. The plant was placed in operation March 9, 1939, and up to this time has operated satisfactorily.

Too much credit cannot be given to our state sanitary engineer for his untiring efforts through the medium of the State Board of Health and his own personal efforts to see that the city might get the most for its money. We feel that this has been accomplished.

Note.—This paper was presented before the Association in its Phoenix meeting May 5–6, 1939.

WAHPETON TREATS ITS SEWAGE *

By George Swiggum

Engineer, Lium and Burdick, Consulting Engineers, Grand Forks, North Dakota

The sewerage system of Wahpeton, built many years ago, consisted of a lateral system of sewers connected to three separate sewer outlets which discharged directly into the waters of the Red River. The new sewage disposal plant, north of Wahpeton, replaces this with a modern system.

* From the "Official Bulletin" of the North Dakota Water and Sewage Works Conference for November, 1939. Published monthly by No. Dakota State Dept. of Health, L. K. Clark, *Editor*.

The disposal works consists of a combined lift station, office building and settling basin, one digester, trickling filter and sludge drying bed. The control building is a three-story concrete circular building 35 ft. in diameter, 37 ft. deep and faced with hollow tile. The lower subsurface stories are divided into two parts with lift station No. 2 forming the west portion of the bottom two floors and the dry pit and the control room forming the east portion of the building. A unique and novel design has been incorporated in this part of the plant since the sedimentation basin or clarifier forms the roof of the entire building.

Sewage entering lift station No. 2 from the main collector system is pumped to the clarifier by any combination of the three pumps in the lift.

Clarifier and Filter

The sewage entering the clarifier has a normal retention period of from 1½ to 3 hours depending upon the normal flow.

The filter bed has an average depth of 7 ft., 6 ins. Only half of the filter is housed. It is planned that the housed portion of the filter will be of sufficient capacity to care for the winter flows thus enabling the outdoor filter to be taken out of service during the extreme low winter temperatures.

Digester

The solids settling to the bottom of the clarifier are pumped to the digester. This is a round tank 30 ft. in diameter and 24 ft. deep located to the northwest of the control building.

The digester is not mounded up with earth as has been the usual practice in North Dakota. Instead of the earth mound, a tile wall is placed outside of the concrete digester wall with an air space of 2 ins. between the two walls. On top of the regular digester cover is placed about 12 ins. of earth and this is covered with another concrete floor. It is believed the above method of insulation will prove as effective as the earth mounds.

The digester is heated with hot water coils supplied by a hot water boiler in which the gas generated in the digester is burned.

Supplementary gas was supplied from pressure cylinders to the boiler when the plant was put into operation. After three weeks of operation, about 1,200 to 1,400 cu. ft. of gas per day was generated. The temperature of the sludge was maintained at about 90°, which is somewhat higher than the temperatures maintained at other plants in the state.

Three beds are provided to dry the sludge from the digesters.

The plant was designed by Lium and Burdick, engineers, Grand Forks, and was constructed by the Meinecke-Johnson Company, contractors, Fargo, at a total cost of $82,415.96. The collector sewer was built by L. C. Byerly, contractor of Breckenridge, at a total cost of $10,961.10. The total construction and other costs of the project in-

cluding the trunk sewer and disposal plant being $101,400.00. Of this amount 45 per cent of $45,630.00 was supplied by the P.W.A.

The entire system was put in operation the third week in September, 1939, when final joint inspection was made by officials of the Public Works Administration and Lium and Burdick, engineers. J. P. Droitcour, resident engineer inspector, was in charge of the inspection for Public Works Administration, assisted by Rubin M. Stee and Walter Johnson.

Rates

On January 1, 1940, the water bills will have an additional charge for Sewage Disposal, covering the months of October, November and December of 1939.

The following charges or rates apply:

Residence of single family occupancy, 75c per month.

Duplex residence, two family apartments connected to one water meter and not using in excess of 6,000 gallons of water per quarter, each 50c per month, each family.

Flats, apartments which are all connected to one water meter, 50c per month, each apartment.

Commercial buildings with apartments on the second floor—commercial part, 75c per month, each apartment, 50c per month.

Commercial buildings, 5c per month, minimum charge, and an additional charge of 9c per one thousand gallons of water used in excess of 25,000 gallons per quarter.

SYMPOSIUM ON "AN OPERATOR'S DAY AT A SEWAGE TREATMENT PLANT*

Discussion Led by Charles C. Agar

Senior Sanitary Engineer, New York State Department of Health, Albany, N. Y.

In arranging the program for this meeting, it was felt that, in view of the large number of sewage treatment plants now nearing completion in New York State, a discussion to bring out the work and duties involved in sewage plant operation would be timely. Such a discussion has, therefore, been arranged to cover both so-called simple and complex plants including the experiences of part time as well as full time operators. This symposium should provide an aid to prospective operators, a basis for discussion by the operators present, and a source of information for consulting engineers, municipal officials and others concerned with the design and operation of plants.

It has been said that consulting engineers sometimes minimize the operating attention that a plant should receive in "selling" a project

* Held at Fall Meeting of the New York State Sewage Works Association, Olean, N. Y., Oct. 6 and 7, 1939.

to the community. As we all know there is more to operating a plant than raking a screen and pushing a button to start a sludge pump. But none of us can fully appreciate the actual work involved until we have lived with a plant through its trials and tribulations.

In visiting plants throughout the State it is a common occurrence to find that an operator is experiencing some difficulties, some serious and others of a minor nature. The consulting engineer is sometimes considered responsible for some oversight or failure to anticipate the condition. But we frequently lose sight of the fact that there are few plants that are perfect in the ultimate sense of the word, where some changes in design or facilities might not have improved control of operation. We are in an age when developments in the art of sewage treatment are being made at a rapid rate and how else can we learn than through experience.

In case of difficulties in operation of new plants the engineer should be the first to be advised for he should be in a position to recommend the most practical changes in either design or operation. The municipality will not only profit thereby but also such experience will be invaluable to the engineer when designing future plants. There should, therefore, be a mutual spirit of co-operation between the engineer and operator so as to further facilitate the development of the art of sewage treatment.

This is the operator's day and in future programs we will plan to discuss the operation of plants from the point of view of the designing engineer.

Discussion by William D. Denise

Superintendent of Sewage Treatment Plant, Town of Greece, Rochester, N. Y.

The treatment plant of the Town of Greece is an activated sludge plant with a designed capacity of 1,000,000 gallons per day to serve a population of 10,000 persons. The plant and sewerage system is entirely new and has been in operation for slightly more than a year. The average flow for that period has been 248,000 gallons per day and the connected population at the present time is 4,100.

The raw sewage has averaged 140 p.p.m. 5-day B.O.D., and 220 p.p.m. suspended solids. We have effected 94 per cent removal of B.O.D., and 97 per cent removal of suspended solids.

The plant embodies the following units: two grit chambers, comminutor, primary tanks, mechanical down draft aerators, final clarifiers with magnetite filters, hopper bottom sludge storage tanks, chlorinators, vacuum filters, and an incinerator. Operation of the plant requires a staff of five men including the superintendent.

At 8 A.M. the operator begins his day's work by taking a reading of the flow meter, oil meter and electric meter, the temperatures of the influent and effluent sewages, air temperatures, wind direction, and weight of chlorine cylinders. He determines the chlorine residual at

8 A.M. and again at 11 A.M.—1 P.M.—4 P.M.—10 P.M. and 4 A.M. He then begins to draw the sludge from the primary tank to the sludge hopper. It is drawn very slowly, an operation requiring usually about 1½ hours. While the sludge is running the operator takes a pH of the sludge in the storage tanks. We try to maintain a pH of 7.6 in these tanks and, if necessary to attain this, milk of lime is added. The supernatant liquor is drawn from the tanks through shear gates at two levels. By keeping the pH at 7.6 the sludge is more concentrated and filters more readily. After the supernatant liquor has been drawn from the storage tanks the primary sludge is then pumped to these tanks. The primary tank is skimmed 9 times daily and the skimmings buried.

Samples of primary tank effluent, aeration tank contents, return sludge, and final effluent are taken daily at 1 P.M., settleability and suspended solids determinations on the mixed liquor and return sludge, dissolved oxygen determinations of the primary, mixed liquor, and final effluents, and a pH of all samples is made.

Every sixth day, hourly samples are taken of raw sewage, primary tank effluent, and final effluent. These are then composited. An hourly sample of the mixed liquor, taken from the channel to the final tanks, is taken in 2-quart jars and allowed to settle for one hour, after which 100 ml. are siphoned off and composited. Samples are taken from a point 1 ft. below the magnetite filter bed three times on sampling day. Upon these samples the following determinations are made: 5-day B.O.D., suspended solids, and settleable solids on the raw and primary sewage.

If the day operator has any leisure time after routine work is completed, it is used for the mowing of about two acres of lawns, painting, repairing, greasing of equipment, cleaning of grit chambers, and many other duties too numerous to mention, all of which are necessary to the successful operation of the plant.

At 4 P.M. the operator on this trick burns all of the rubbish that has accumulated during the previous 24 hours. During the summer months he works around the yard and completes the work started by the day operator. After dark the daily cleaning of the buildings is started and this work is continued by the operator starting work at midnight. The buildings and equipment are thoroughly cleaned each 24 hours, and if necessary the floors are waxed.

At daylight the operator flushes and hoses down the tanks and channels. This task requires about 2 hours.

At present it is necessary to dewater and incinerate about every 10 days. This usually requires about 30 hours. At this time two operators work on each trick for 12 hours. During the process of incineration samples of sludge are taken and composited each hour. From these samples pH and dry solids are determined. Three samples of filter cake are taken each hour and weighed to determine the weight of the cake to the incinerator. After weighing these samples a small portion is used for moisture and volatile determinations. After in-

cineration about 12 hours are devoted to thoroughly cleaning the filter and incinerator rooms.

This, I believe, completes the schedule for 24 hours operation of our plant.

The personnel takes real pride in the appearance and up-keep of the plant and its surrounding grounds, and visitors are enthusiastic in their praise of the standards maintained.

Discussion by Glenn A. Williams

Superintendent of Public Works, Cuba, N. Y.

The sewage treatment plant at Cuba consists of an Imhoff tank with a capacity for a population of 2,500. Cuba now has a population of about 1,750.

The plant is visited three times daily. The first visit is made about 7:30 A.M. at which time the gas vents are given attention and stirred up by breaking up the floating solids so the gas will vent freely. If there is any scum on the tank this is also broken up so it will settle into the digestion chamber. The slots are kept clean by the use of a large chain dragged through the openings. I have at different times used a fire pumper to break up the solids in the gas vents, pumping the water from the creek nearby. Grease and scum are removed from the tank and buried or dried and burned.

I visit the plant again between the hours of 10:00 and 12:00 A.M. at which time I make a test for residual chlorine, as this is the time when the sewage flow is at its peak. The amount of chlorine used is from 18 to 20 lb. per 24 hr., showing a residual of 0.5 p.p.m. at the peak flow of the sewage. I do not change the rate of chlorine treatment for different changes in the sewage flow; that is, the same amount of chlorine is fed into the tank at all times.

Care of Chlorine Apparatus

The chlorine machine used is of the manual control dry feed type. Careful attention is given to any leaks. A full set of gaskets is on hand at all times. The machine is kept painted and well greased. Every two weeks during the change of tanks I pump carbon tetrachloride through the machine. I find that in doing this it keeps the small openings in the machine free of "dry chlorine" and also keeps the compensator valve working freely as well as the back pressure valve. Every month I remove the diffuser and clean it with warm water. In doing this I find that the setting of the manometer scale will correspond with the amount drawn from the chlorine tank in the 24 hours and the back pressure gauge will show about 10 pounds.

Pumping of Sludge

The time for pumping is determined by the depth of the sludge in the digestion chamber which is measured with a pitcher pump with a

hose attached marked off in feet. When the sludge depth is about 4 ft. the plant is pumped and the sludge is drawn down to about 18 in. Care is taken not to remove all digested sludge. The sludge is pumped onto drying beds, of which there are two. The drying time on the beds depends upon the weather as our beds are not covered. When the sludge is thoroughly dry it is removed and hauled away to farmers. This we do as I have found it hard to dispose of it in any other way.

Settleable Solids Test

I make a settleable solids test at least twice a month. These tests are made with Imhoff cones and are made when the sewage flow is at its peak. In making these tests I do not collect both samples at the same time. I collect a sample from the influent first. In about an hour a sample is taken from the effluent. This is done in this way as the detention time of the tank is about one hour. This I have tried to time by using bluing but without much success.

Buildings

There are two buildings. One is for the sludge pump and one for the chlorine machine. These buildings are painted with aluminum paint trimmed with green. I find that aluminum paint gives the best service around chlorine fumes of any that I have tried. The steel I beams over the tank are painted with red lead and oil. This keeps them from rusting from the gases rising from the tank. Heating is done with an oil stove which gives good results, as the plant is not near a gas service. This type of heating is very reasonable in regard to fuel in the coldest months of the winter. The consumption is only 2 gal. per 24 hr., with fuel oil at 8 cents per gallon, or 16 cents per day.

The outside of the Imhoff tank is painted with white traffic paint, which stays well and gives the plant a better appearance. I hope in the very near future to set out some evergreen trees around the plant and improve the grounds. We have done some filling and grading and are ready to seed some of it. The location of the plant makes it hard to keep the grounds in nice shape, as it is located near the creek, which overflows during high water and washes the grading out.

Sewer System

I make inspection trips of the sewer system about every month, at which time all inverts are flushed out. I have had some trouble with roots in the sewer system until we purchased sewer cleaning equipment, which does a real job of cleaning sewers. I have taken out as much as five bushels of roots in 300 ft. of 18 in. sewer, which was on the main trunk line. A also find by putting the cleaning equipment through sewers where the flow seems to be good that we get roots if there are any poplar trees near the sewer line. I also find that elm trees are almost as bad for sewers as poplar trees. We have had stoppage in sewers from soft maple roots also.

DISCUSSION BY JOHN C. STROWBRIDGE

Superintendent of Water and Sewers, Dundee, N. Y.

Our plant is situated in the village of Dundee, Yates County, New York, midway between Penn Yan and Watkins Glen, and about three miles west of Seneca Lake.

The plant was built in 1929 and consists of a pre-chlorination contact mixing chamber, two covered hopper-bottomed settling tanks, a sludge sump and pump, and two glass covered sludge drying beds, each 17 by 74 feet.

My time is divided between the care of this and the village water works plant. I time my daily visit to the disposal plant as near 9:00 A.M. as is possible. The daily routine is started with filling out the daily record of the monthly report to the State Department of Health. These records cover the temperature of the air, direction of the wind, weather conditions, temperature of the sewage, residual chlorine at the effluent and the depth in inches of the flow of water over the weir, which is converted to gallons per day.

The routine care of the sewage is as follows: The receiving chamber is inspected and the sewage is stirred and the chamber flushed each day. A sample of the raw sewage is tested for settleable solids by the Imhoff cone. This sample is allowed to settle in the cone for 45 minutes, is then shaken and left to stand for another fifteen minutes before a reading is taken and recorded. After this the cone is cleaned for future use.

After leaving the mixing chamber the sewage passes into the settling tanks. There are two of these tanks, each 18 by 52 feet. One is used at a time while the other is digesting. Tracing the course of the sewage through these tanks will indicate approximately the requirements necessary in the care of this part of our work. The active tank receives the sewage direct from the mixing chamber. In this tank the solids separate from the water and are deposited in the bottom of the tank. The water from the tank passes out over the weir into the sewage outlet. When the solids in this tank have reached a depth of 5 ft., more or less, the flow from the mixing chamber is shifted to the second tank which becomes the active unit. The solids in the first tank then start digestion which requires about three months for completion. During this period the tank is under frequent inspection and from time to time is thoroughly stirred, and all scum that has formed is broken up.

When the digestion is completed the residue is pumped to the sludge beds. There the water from the tank is allowed to drain off and the solids that remain are dried on the sludge beds. This process requires the changing of the ventilators on the enclosure twice each day. When dried the sludge is removed for fertilizer. The cleaning of these sludge beds requires raking and leveling and sometimes resanding. The complete process requires practically a day, three or four times each year.

The flow from the effluent weir is tested for residual chlorine, morning and evening, each day. Three times a week an Imhoff cone test of this effluent is also taken.

The general sewer system, other than the disposal plant, is flushed and inspected each spring and fall and any defects that may be found are repaired. Some parts of the sewer system require more frequent inspection and care because of the presence of ground water and quicksand.

The chlorination house requires care at least twice each day during cold weather for protection against freezing. A coal stove and electric bulbs are used for heating. The tanks of chlorine have to be transferred from the station to the plant once each month. The installation of new tanks is necessary about three times each month. The chlorinator is cleaned twice each year and is given daily inspection. These chores all take time.

An inspection of Big Stream Creek, into which the effluent discharges, is made at least once each month.

This summer nearly a month was spent in repainting the sludge bed enclosure and other buildings. The replacement of broken glass in the drying house is an item of work from time to time.

In addition to the foregoing, considerable time is required to keep the plant clean and in order, and in summer our lawn requires frequent attention. In general, we think that the care of such plants should be considered as furnishing a full time job.

Discussion by H. D. Hutcheson

Chief Operator, Sewage Treatment Plant, Newark, N. Y.

At our plant three men are employed regularly, 8 hours per day, changing off so that each one works every third Sunday. We have extra help when necessary and usually have two extra men from May 1st to October 1st each year.

During February of each year I submit a list of recommended maintenance work and changes to be made during the year at the plant. I will now read you the list submitted last February.

Maintenance Work to be Done in 1939

All tanks scraped and painted.
All iron work painted.
Gas holder scraped and painted.
Concrete around tanks repaired.
Building cracks repaired.
Gas dome No. 1 Digester rebuilt.
Gas engine overhauled.
Glass house to be overhauled.
Buildings painted.

Changes and Installations to be Made in 1939

Deep well outside digesters to be completed.
Tunnel for suction header to be completed.
Suction header to be installed.
Discharge header to be installed.

Supernatant liquor detector to be installed.
Connections between Digester No. 2 and Gas Holder changed.
Pump and pipe line installed in Deep Well.
Connections between Digester No. 1 and Digester No. 2 changed.

From the records of the previous years we have discovered that to keep the plant operating in a favorable condition we would be compelled to dispose of a considerable amount of sludge that our digesters and dry beds would not accommodate, so it was decided that we build a tank truck and endeavor to have the farmers haul out the sludge in liquid form as a ground conditioner and fertilizer experiment. So we built the truck and put it in operation, as I will show you later.

In our maintenance and change operations we had considerable concrete to drill and chip, and found we would be unable to hire the air-compressor we formerly used so we prevailed upon the Board to allow us to build a compressor, which we did.

I have mentioned these things to show you the various kinds of work that are always staring you in the face if you wish to maintain your plant and keep it up to date. These things are all in addition to the regular and daily operation of the plant.

Now I am going to select a day—September 13, 1939—typical of any ordinary day during the summer when the whole five men are on the job. I was going to select September 9th so that I might have proof of my statements by Mr. Marshall of Geneva, who was at the plant that forenoon but did not stay all day, and besides the whole five men were not working that day. I will refer to the five men as No. 1—2—3—4—5, No. 1 being myself, chief operator, No. 2—1st assistant, No. 3—2nd assistant, Nos. 4 and 5 as laborers. No. 1—I went to the gas holder to check on the amount of gas, then to inspect the primary tank, aeration tank and final tanks, also the return well and head block for visual conditions.

The Jackson Perkins Company furnished a truck driver for the tank truck to haul wet sludge. The sludge is loaded from a standpipe outside the dry house with a shut-off valve on the inside, and to illustrate the amount of work necessary to carry on the regular operation and at the same time load sludge which all has to be pumped, there were 76 valve operations that day, of which I performed 60 and No. 3 performed 16.

When hauling sludge we average 7 loads per day and we have hauled out nearly 500 loads this year, so you can see this is not a one day performance. In addition I made pH tests on influent, primary, aeration and final effluent besides the 30-minute settling tests. Attended to a steel salesman, furnished him with blueprints and other dimensions to retread the drive wheels on the clarifiers. Also another salesman from whom I ordered a resistance coil for direction signal switch on tank truck, also a flexible tubing for an exhaust pipe. Aside from this the street department sent down a bent street light pole for which I had to assemble the acetylene cutting outfit and cut off the pole.

You may well ask if I did all this what were the other four doing?

I will endeavor to explain. As you will remember we had on our list of changes a supernatant liquor detector, this could only be applied when our storage tank was empty and for the first time this season we had the tank empty. Nos. 2 and 4 with the air compressor drilled four holes in this tank in vertical lines, each one large enough to receive the flange on a 4 in. cast iron pipe, then assembled and lined up these four pipes through the wall so when concreted in they would line up to connect to our assembled 4 in. standpipe made of 4 in. stock crosses. Nos. 2 and 4 completed this work drilling the holes, placing and aligning the pipes and concreting same in, ready for valves so the tank could be put into operation. Putting away all tools and cleaning up completed this job.

No. 5 put in the greater part of the day mowing the lawn and trimming the shrubbery.

No. 3 raked the screens the usual number of times, congregated the concrete material mixing box and tools; cut 6 ⅝ in. threads 3 in. long each on steel bolts, replaced a gasket on a Barnes sludge pump, cleaned the pump valve chambers and safety relief valve on the same pump. This pump, having blown a gasket while pumping sludge from storage to the tank truck, littered up the pump room considerably and this No. 3 cleaned. He then made his daily rounds to the two pumping stations at either end of the village. At one station he found the float line had stretched so that it did not cut out the motor; this he repaired and thus endeth another day.

You will remember I read you a list of maintenance work and changes for 1939; of these the following have been done:

All tanks scraped and painted.
All iron work painted.
Concrete around tanks repaired.
Engine overhauled, with new cylinders, piston rings and pins.
One side of roof of glass house puttied, building is 80 ft. by 160 ft.
Trim on all the buildings painted.
Deep well outside digesters completed.
Discharge 6 in. header installed.
Connections between No. 2 digester and gas holder changed.
Pipe line installed in deep well outside digesters.
Supernatant liquor detector 75 per cent completed.

In addition we had the 4 in. shaft 70 ft. long in an aerator wear through and buckle. We had to weld and assemble a new shaft.

This is to show you we have had other days besides September 13th.

Discussion by A. H. Woefle

Foreman, Sewage Disposal Plant, Dunkirk, N. Y.

Before going into the duties of caring for the sewage disposal plant a description of it will help to explain its operation.

Our plant is equipped with Dorrco mechanical bar screen, Dorrco detritor, sewage wet well, pump house, Imhoff tanks, chlorine reaction tanks, glass-covered sludge beds and chlorination apparatus.

We work in three shifts, two men on the day shift and one on each night shift in addition to a relief operator, making a total of five in all. Each man has one day a week off.

The men on the day shift report for work at 8 A.M. They first confer with the night men to ascertain if there was any trouble and if there are any repairs to be made. Temperature readings are taken, residual chlorine tests made and weather conditions are recorded before a general inspection of the plant is made, after which the Imhoff tanks and dosing tank are washed and skimmed. About every hour the screen is cleaned and washed and four or five times during the eight-hour shift the pumps and bearings are gone over to see that they are always well lubricated. Before leaving the shift there is a general cleanup of shafts, oil cellars and pumps, a residual chlorine test and recordings made and tanks weighed.

At 11 A.M. one liter of the influent and one liter of the effluent for the cone tests is taken and at 1 P.M. the cone readings are taken and recorded. On Tuesdays and Fridays grit is taken out of the screen pit (which is 30 ft. in the ground) and placed in refuse cans by means of an electric hoist onto a loading platform in readiness for the garbage collector. Skimmings and screenings are disposed of along with the grit.

To draw sludge the depth is measured first. For this a pitcher pump and a 1¼ in. hose is used. After the depth is measured and sludge drawn a sample is taken for pH test from each hopper together with a temperature reading of the sludge. We usually draw to a depth of about 10 to 12 in. on the beds. Enough sludge is left so that the hoppers are always full. By so doing we are sure to have enough well-ripened slude to seed the fresh sludge coming in. It takes from 45 to 90 minutes to draw the sludge, depending, of course, on its condition.

The plant is located on about two acres of land. Considerable time is consumed daily in taking care of the lawn, shrubbery, flower beds and evergreens. Glass has to be replaced at frequent intervals, painting to be done and sludge removed from drying beds. The sludge is given to the farmers for the hauling. During the summer months when the farmers are busy it sometimes has to be removed by the street department trucks.

In addition to this work there is the replacing of packing in pumps, changing of the chlorine tanks when empty and replacing of sand on beds about once in two or three years. Besides all general repairs we also do all of our own plumbing and make all additions and repairs to electric service except the 2,200 volt motors. The plant is situated on the shore of Lake Erie and during the winter there is plenty of snow to take care of. Our floors are swept and mopped regularly and the windows are cleaned at frequent intervals during the year.

I have tried to give a general idea of the work involved in what I think is keeping a sewage disposal plant in good condition as well as a beauty spot.

We invite your inspection of our plant at any and all times.

Editorial

THE NEW JERSEY MEETING

The New Jersey Sewage Works Association has just held its Twenty-fifth Annual Meeting at Trenton on March 20 to 22, 1940. For several months curiosity and interest have been awakened concerning this meeting because of announcements that the program would be of national scope and the meeting would be the start of a national sewage works association. The program included papers by several men from the middle west and many more from New Jersey and the east. The plans for a national sewage works association, as discussed by Mr. William Orchard, of Wallace & Tiernan Company, coincided closely with the objectives for 1940 announced by the Federation at its annual meeting in January, as published in This Journal on pages 163 to 167 of the January issue. These objectives included broadening the scope of the Federation's activities, strengthening the central office by additional secretarial help, arranging for more committee work, planning a national meeting in the fall of 1940, with exhibits by manufacturers of sewage treatment equipment, planning monthly publication of the Journal in 1941, and building up the prestige of the Federation as a public body of united and coordinated influence in matters of public policy.

These objectives have been under consideration for a long time by the leaders of the Federation, especially Mr. Orchard, who discussed the question of expansion at the meeting in January, 1939, and who began to make plans for the big New Jersey meeting in the fall of 1939. The successful meeting just held at Trenton, with approximately 450 registered and exhibits by 35 manufacturers, demonstrated what could be done by a state organization of several hundred members, when backed by a small group of men experienced in the running of conventions, and with funds sufficient to underwrite the numerous expenses of a large convention. Mr. Anthony Auable of the Dorr Company, Mr. Harry P. Croft, State Sanitary Engineer of New Jersey, Mr. Linn Enslow, Vice-chairman of the Federation, and the convention committee of the New Jersey Association, were able lieutenants to Mr. Orchard, and altogether they put over a bangup convention.

Now where do wo go from here? The ball has started rolling and work is under way to realize the objectives stated above. A committee is at work on plans for the Federation convention. These plans will be announced in the next (May) issue of this JOURNAL. The meeting will probably be held in conjunction with that of one of the larger local sewage works associations, for it was made very clear in open discussion at the New Jersey convention that the present plan of strong local sewage works associations, with their own annual conventions, must be continued. The growth of these various associations, each with its distinctive characteristics, has been the main feature of strength of the Federation, and the plan has been too successful to warrant tampering with it. When the Federation was planned by those great leaders now gone, George W. Fuller and Harrison P. Eddy, the relative advantages and disadvantages were considered of (1) a central association, possibly associated with the American Water Works Association or the American Public Health Association, divided

into district or state branches, or (2) a development of strong local or regional associations, with a national chairman and secretary, and a national journal for publication of as many papers as possible from all over the United States and abroad. The latter procedure was adopted, and its success has proven the wisdom of those far-seeing men. The local associations have a zest and character representative of the regions they represent. Closely knit groups of operators, research workers, state and municipal sanitary engineers, and university teachers strongly hold their local associations together by a community of interests, a pride in their local affairs, and above all by the physical and financial ability to attend the nearby annual conventions, whereas it might be impossible to attend an annual convention at a distant city.

After the plan of formation of independent local groups was adopted, the problem arose as to how the national journal could be started. It was providential that Dr. Rudolfs found the man who could and would underwrite the JOURNAL, at the meeting of the American Chemical Society in St. Louis in 1928. The breakfast meeting with Mr. Buffum is still clear in the writer's memory, and through all the intervening years Mr. Buffum has never failed to do all and more than he promised at that time. Estimates of the field of circulation of the JOURNAL, then ranged from 1,000 to a maximum of 1,200 and no one present thought that there would be around 3,000 subscribers within ten years.

Now, however, in 1940 the success and prestige of the Federation are assured. The only question is how it can be of more service to its members and to the loyal manufacturers who by their advertising have provided most of the funds that have made the JOURNAL and Federation self-supporting for the past three years. Mr. Orchard has taken the lead for the manufacturers to point out how the Sewage Works Federation can go on to wider and more helpful service as a thriving and an essential organization in the field of sanitation. He has made suggestions as to how the money can be raised to finance this service, in part by increase in dues, and in part by increased support by manufacturers. Mr. Orchard's suggestions deserve prompt and careful consideration by all associations that are members of the Federation, and Mr. Emerson is doing everything possible to present to them the plans for future action, in accordance with his announcement in our January issue.

The New Jersey Sewage Works Association has not been a member of the Federation, but at the Trenton meeting a resolution was passed empowering its officers to act for or against national affiliation. There is no doubt that the Federation would welcome the New Jersey Association, and it seems almost inevitable that such affiliation would prove to be mutually helpful.

F. W. MOHLMAN

Proceedings of Local Associations

CALIFORNIA SEWAGE WORKS ASSOCIATION

Twelfth Annual Fall Convention, Oakland, California, September 18–19, 1939

The Twelfth Annual Fall Convention of the California Sewage Works Association was called to order by President Alexander Bell at 9:00 A.M. Monday, September 18, 1939, in the Mezzanine Parlor of the Hotel Leamington, with 80 members and guests in attendance.

In opening the meeting, President Bell said there was a very full program ahead, but that the meetings would be kept on time so that members of the Association and their guests might keep appointments to visit the Golden Gate International Exposition on Treasure Island.

A brief résumé of the Directors' meeting was given by President Bell, who then called upon Wm. A. Allen, Chairman of the Operators' Breakfast, for a report. Mr. Allen reported that the Operators' Breakfast, an innovation, was a huge success, and that the 26 operators present unanimously voted to hold such a breakfast for the discussion of operators' problems at each future convention and conference. The principal items of discussion were plant records and mechanical equipment; the conclusions being that good records should reflect the behavior of the plant and its operators, thereby giving much assistance in case of law suits; and that ball valve sludge pumps foul easily and are most difficult to maintain.

Committee reports were called for and Fred Bowlus, Chairman of the Membership Committee, responded first, saying that while the goal of 300 members by the Fall Convention was not attained, the Association had a healthy growth, particularly of new sewage treatment plant operators, the paid up memberships as of date being 263. It was further reported that but 26 members were in arrears in dues.

Mr. John A. Clark, Chairman Publicity Committee, stated that at the time of his reporting over 200 column inches of publicity had been given to the Fall Convention by the Metropolitan Dailies. He exhibited an excellent scrap book containing publicity clippings appertaining to the Visalia Spring Conference and Oakland Convention to be passed on to the new Chairman of this Committee. In closing, Mr. Clark acknowledged the assistance given him by Mr. Bob Van Etten, Educational Assistant of the Alameda County Mosquito Abatement District.

Chairman J. F. Smith of the Finance Committee reported that while there was a small deficiency in the financing of Vol. XI, No. 1 of the *C. S. W. Journal* that additional advertising had been obtained for Vol. XI, No. 2, restoring the publishing of the *Journal* to a sound financial basis.

Mr. A. M. Rawn, Chairman Legislative Committee, reported the committee had taken no action since the Spring Conference.

President Alexander Bell said the report of the Award Committee would be made at the Joint Breakfast meeting with the Engineers Section of the League of California Municipalities. Mr. May's written report as Chairman of the Award Committee is published elsewhere in the *Journal*.

Mr. A. Perry Banta, Chairman of the Certification and Schools Committee, submitted a written report, which is printed elsewhere in this *Journal*.

The standing committees having reported, a call for reports from special committees was made.

R. Pomeroy, Chairman of the Fact Finding Committee, stated that his committee had assembled much information upon primary clarifiers and that a report of findings upon this unit of the sewage treatment works might be presented at the Spring Conference in 1940. A program is laid out for the committee to study in a predetermined order the several components of sewage treatment plants.

Mr. William T. Ingram, Secretary-Treasurer San Joaquin Section, submitted a report of the Section which is printed in the *Journal*.

The report of the Nominating Committee, consisting of Wm. A. Allen, Ben Benas and A. Perry Banta, was made by Chairman Allen. The following members were placed in nomination:

For President, H. G. Smith; First Vice-President, Harold F. Gray; Second Vice-President, Fred Bowlus; Director 1944, Alexander Bell; Director 1941, to fill the unexpired term of A. M. Rawn who presented his resignation due to pressure of other business, Harold Jewell; Secretary-Treasurer, William T. Ingram.

There being no other nominations from the floor, it was moved, seconded and carried that the Secretary cast a unanimous ballot for the candidates as nominated by the Nominating Committee.

The Secretary explained the proposed Constitutional Amendments, saying that they were approved by the Directors as printed and distributed to the members as an enclosure with the program for the Convention. It was asked if anyone desired to discuss or question any of the amendments. There being no discussion, it was moved, seconded and carried that the amendments be approved as printed.

Under new business it was moved by R. Pomeroy and seconded by A. Koebig that a short school for operators be held every year at the University of Southern California.

In discussion of the motion, Mr. Banta said that the few members who have put on previous schools at Los Angeles would not welcome the work entailed in a course every year and that such a program would bring an early climax to the schools.

Mr. Wm. A. Allen moved that Mr. Pomeroy's motion be tabled. This motion was seconded and carried.

The business meeting was closed promptly at 10:00 A.M. and the technical session opened.

The first paper, "Problems in the Operation of the City of San Francisco Richmond-Sunset Sewage Treatment Plant," was presented by Mr. Ben Benas, Superintendent of the plant. Mr. Benas' paper was followed by brief written discussions by Keeno Fraschina and R. R. Sotter, Assistant Superintendent and Chief Operating Engineer, respectively, of the Richmond-Sunset Plant. Professor Charles Gilman Hyde gave a most interesting extemporaneous discussion of Mr. Benas' paper which brought out many items as food for thought.

The second paper, "Sewage Pumping and Disposal at Treasure Island" was presented by Chas. H. Lee, Chief, Division of Water Supply and Sanitation, G. G. I. E.

Mr. Morris Cohn, Editor of *Municipal Sanitation,* was introduced and extended the greetings from the East to the West.

Announcement was made of the caravan for the afternoon and the meeting adjourned for luncheon.

At the noon luncheon Walter N. Frickstad, City Engineer of Oakland, extended a word of welcome on behalf of Mayor McCracken of our host City. Mr. Frickstadt told of the sewage disposal problem of the City of Oakland and its neighbors and said that the warm Indian summer weather, a low tide and gentle westerly breezes would fully acquaint those attending the caravan in the afternoon with the seriousness of the situation existing along the Bay shore.

President Bell in reply remarked "that it is gratifying to find that the East Bay Cities are attacking a difficult problem in a serious manner" and offered the services of the C. S. W. A. should they be of any assistance.

The afternoon was occupied by a caravan to visit the City of San Francisco sewage disposal facilities consisting of the New Marina Sewage Pumping Plant which is completely underground, the only evidence of its presence above ground being a flag pole vent; the Golden Gate park activated sludge plant treating about a million gallons of sewage per day, the effluent from which is used for irrigation and to create park lakes; and the new Richmond-Sunset Sewage Treatment Plant located in the most westerly end of Golden Gate Park, placed in operation in April, 1939, and treating the sewage of a residential area with a present population of 150,000 and an estimated future population of 300,000.

The Tuesday program opened with a joint breakfast of the Association and the Engineers Section of the League of Municipalities in the Castilian Room of the Hotel Leamington, with President Harry Goodridge of the Engineers Section of the League presiding. A humorous talk on astronomy by Max Horwinski started the morning with a good laugh.

The gavel was given to President Bell for the purpose of presenting the Award of Merit. Chairman May gave a brief report of the Award Committee and President Bell presented the first award, a metal plaque and a check for $25.00, to Mr. A. J. Castro, operator of

the Santa Clara sewage treatment plant. The second award was won by the city of Lodi. The third award was not made.

The technical session was called promptly at 9:00 A.M. by President Alexander Bell in the Leamington Bowl. There were 120 members and guests in attendance.

Three papers were presented. Col. Edwin C. Kelton's paper, "Pollution of Navigable Waters or Interstate Streams from the Standpoint of the Federal Government," was read by Captain N. A. Mathias and was discussed by A. M. Rawn.

Howard Vernon, for many years the champion of the sportsmen's case for the curtailment of pollution, read his paper, "Pollution of Harbors and Streams from the Viewpoint of the Sportsman."

The third paper, "Pollution of San Francisco Bay and the Effect of Sewage Treatment," was presented by the author, A. B. Crowley, and was discussed by J. F. Byxbee.

After the introduction of guests and a short address by Morris Cohn, the meeting adjourned.

R. R. RIBAL, *Secretary*

GEORGIA WATER AND SEWAGE ASSOCIATION

Eighth Annual Georgia Water and Sewage School, Atlanta, Georgia, October 18–21, 1939

The Eighth Annual Georgia Water and Sewage School sponsored by the Georgia Department of Public Health, the Georgia Water and Sewage Association, and the Georgia School of Technology, brought 273 men to the Georgia Tech campus October 18–21. This record breaking attendance of 241 water and sewage plant operators and other officials of Georgia municipalities, and 30 manufacturer's representatives was matched by the enthusiasm with which those present entered into the spirit of the school to secure the greatest benefits from the water purification and sewage treatment instruction. In addition to the above, 25 senior class students in the Civil Engineering and Public Health Engineering Departments of the Georgia School of Technology "sat in" on all sessions of the School.

Methods of instruction at the Georgia Water and Sewage School employ lectures, blackboard diagrams and charts, laboratory demonstrations, plant inspections, and discussions of each topic rather than the reading of prepared papers. The classes are actually taught and definite solutions to typical problems are given. Special or unusual problems are presented by the students for discussion and there is usually a solution suggested by someone who has had a parallel experience. This principle of mutual instruction has built up a splendid *esprit de corps* which has become a predominating characteristic of the school. It is believed that these classes bring together for serious study the largest group of water and sewage operators, superintendants and other municipal officials which annually assembles in the

southeastern area of the United States. All distractions from attendance at classes are prevented and no elaborate entertainment is furnished. The college campus provides the proper atmosphere for the school.

Manufacturers are supplied with an exhibit room where equipment can be demonstrated and explained. Models and educational material are loaned by nearby water and sewer departments and personnel assigned to show their purpose. Gadget displays are featured. All facilities are utilized and coordinated to give the student a better knowledge of available water and sewerage material and equipment.

Dr. M. L. Brittain, President, Georgia School of Technology, welcomed the group to the campus expressing delight that the facilities of the college could be made available for service to water and sewage men and commented upon the mutual helpfulness of the annual contacts between the college and the persons directly responsible for water purification and sewage treatment in Georgia.

Dr. T. F. Abercrombie, Director, Georgia Department of Public Health, added his welcome to that of Dr. Brittain and reviewed the history of the Georgia Water and Sewage School drawing a word picture from its beginning in 1932 with an attendance of approximately 60 to the peak attendance in 1939. Georgia's death rate from typhoid fever is now at its lowest point. Dr. Abercrombie gave credit to Georgia water and sewage plant operators and the extension of water and sewage service within the last several years for their part in reducing and maintaining this death rate at its present low level. Mr. Lloyd L. Jacobs, Newnan, President, Georgia Water and Sewage Association, responded to the two addresses of welcome and expressed appreciation to those persons who had worked tirelessly in planning and preparing the school schedule. An explanation of the course of instruction and recognition of the men attending the school for the first time by W. H. Weir, Georgia Department of Public Health, closed the opening session in preparation for the classroom work and laboratory demonstrations.

A number of the instruction courses were of interest to all water and sewage plant operators and these were given to the entire assembly. The laboratory work and a number of the discussions were given to separate water and sewage groups.

Selection and Maintenance of Pumps.—Thos. M. Lowe, Professor of Civil Engineering, Alabama Polytechnic Institute, Auburn, Alabama, gave a very informative and easily absorbed talk on the selection and maintenance of centrifugal pumps. Charts were used to demonstrate the manner of choosing the most efficient pump for a job. It was stated that there is a general tendency to choose a pump with too large an impeller for best efficiency. An over size pump should never be purchased in anticipation of future expansion as the over size pump will be inefficient in its under sized surroundings and will waste enough money in power consumption to buy several pumps before the time for expansion arrives. Centrifugal pumps should be inspected

internally at intervals not exceeding six months and sealing rings should be replaced when showing signs of wear. Oil or grease in the pump should be watched closely for black discoloration which is a sign of undue wear on the bearings. The pump packing gland should never be tightened too much, and when packing the pump if all of the packing is not replaced with new then the back packing ring should be removed and the rest moved up placing the new ring on the outside.

J. C. Boesch, Jr., Assistant Engineer, Martha Mills, Silvertown, Georgia, described his experience with pumps at the Goodrich Martha Mills. It was shown by hypothetical cost date that the economical degree of efficiency sought in the purchase of a pump is determined to a great extent by the use of the pump. For instance, it is undoubted economy to pay a large premium for the most efficient pump if that pump is to work 24 hours every day; but it may be more economical to buy a cheaper and less efficient pump on duty for an hour or so each day.

It was brought out in a general discussion that metering devices are an important part of even the small water and sewage plants so that constant check may be had on pump efficiencies.

Sewage Treatment.—G. R. Frith, Assistant Engineer, Georgia Department of Public Health, was in charge of instruction in sewage laboratory work. The tests covered were mainly those applicable to the small sewage plant laboratory. Inasmuch as the relative stability test is still found useful for the small plant with secondary treatment Dr. S. H. Hopper, Georgia School of Technology, gave a very interesting demonstration of the action of methylene blue when incubated with secondary sewage effluents. The methylene blue changes to the leuco base which is white, or colorless. This change is caused by the addition of hydrogen to the methylene blue molecule by natural processes during incubation.

Carl Wesley, Chemist, Atlanta Sewer Department, demonstrated and discussed the B.O.D. determination, including the use of the Rideal-Stewart modification.

At the round table discussion on sewage treatment G. R. Frith led with a résumé of the life cycle of the trickling filter fly. Methods of control were discussed and it was pointed out that the length of the life cycle varies greatly with temperature. In Georgia where a temperature between 75° F. and 85° F. prevails most of the summer months the life cycle becomes as short as seven days. Sewage plants are built primarily to treat sewage and care should be used, where filter flooding is employed as a fly control method, not to flood oftener nor keep the filter out of service any longer than is absolutely necessary.

Mr. Wm. A. Hansell, Assistant Chief of Construction, Atlanta, spoke of his experience in operation of the Atlanta plants. It was mentioned that the Atlanta plants, being new, are not yet up to total capacity and it has been possible to practice both flooding and drying for fly control on certain of the Atlanta trickling filter units without detriment to the plant effluent.

During the general discussion it was brought out that very few of the operators had occasion to inspect the paint on the under-water steel work in their plants. L. L. Jacobs, Superintendent, Newnan, stated that it had been necessary to repaint the under-water steel work at their two plants and that the hot bitumastic enamel coat applied last is still in good condition. G. R. Frith called attention to the fact that fresh sewage is apparently less corrosive than the soft surface waters of Georgia since ferrous metal chains last much longer in the sewage plants than when used for similar service in surface water filtration plants.

It was brought out by E. J. Graves, Operator, Moultrie, Georgia, that although time clocks were installed on his sludge pumps he had found it necessary to regulate the day sludge pumping program by hand in order to keep the primary tanks free from floating sludge and scum. This is especially true where one sludge pump is connected with more than one sludge hopper as the sludge does not seem to have the same viscosity in any two hoppers.

During the discussion of sludge digestion it was pointed out that the pH of the digester supernatant liquor in tanks without stirring mechanism cannot be taken as representative of the pH of the sludge. In such tanks stratification takes place resulting in great variation in pH values at different points.

Inspection Trip.—An outstanding feature of the School was the day devoted to the plant inspection tour. The motorcade of fifty-two automobiles began the ninety mile trip by leaving the campus immediately after breakfast.

Upon arrival in Newnan a barbecue lunch was served in the beautifully landscaped Harvey H. North Park surrounding the water plant. City Attorney Freeman welcomed the School to Newnan and paid tribute to Harvey North, Chairman, Water and Light Commission, for his long service in developing the present public utilities of Newnan. Immediately after lunch Lloyd Jacobs and local personnel served as guides in the observation tour of the impounding reservoir and water purification plant. The tour continued with inspection of the East Side Sewage Plant to illustrate operation details in controlling primary clarifier, separate sludge digester, trickling filter, and final clarifier. To illustrate filter larvae destruction, the trickling filter had been flooded and was partially drained during the visit. The tour was concluded at the municipal swimming pool which had been placed in "off season" operation to show modern swimming pool water purification equipment.

Georgia Water and Sewage Association

The complimentary banquet given by H. M. Thompson, Resident Manager, Paper Makers Chemical Division, Hercules Powder Company, Atlanta, provided a delightful occasion for 267 members and guests of the Georgia Water and Sewage Association who attended the

Annual Business Meeting at the Ansley Hotel in Atlanta. Following the banquet and business meeting a travelogue motion picture in natural color—Atlanta to Alaska—made by Warner V. Flowers, City Councilman, College Park, was shown. This motion picture covered an automobile and boat trip of approximately seven thousand miles and records many of the works of man and natural beauty spots in the west and northwest section of the United States and Alaska.

The report of the Secretary of the Georgia Water and Sewage Association showed that there was an increase in membership of 106 during the last year, making a total membership at the present time of 277.

The following officers of the Georgia Water and Sewage Association were elected: *President,* Clark W. Jones, Superintendent Water and Lights, Dalton; *First Vice-President,* J. C. Boesch, Jr., Assistant Engineer, Martha Mills, Silvertown; *Second Vice-President,* George H. Sparks, Superintendent of Water and Lights, East Point; *Secretary-Treasurer,* Paul Weir, Superintendent of Filtration, Atlanta (re-elected). The following were re-elected to the Certification Committee: Carl Alexander, Superintendent of Filtration, Rome; O. W. Gray, Chemist, Water and Light Department, Thomasville; H. A. Wyckoff, Professor of Biology, and John L. Daniel, Professor of Chemistry, Georgia School of Technology. Lewis Simonton, Superintendent of Water Purification and Sewage Treatment, Griffin, and G. R. Frith, Assistant Engineer, Georgia Department of Public Health, were re-elected to the Board of Control of the Federation of Sewage Works Associations.

G. R. Frith,
Member, Board of Control, Federation of Sewage Works Association

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NEW YORK STATE SEWAGE WORKS ASSOCIATION

Twelfth Annual Meeting, New York, N. Y., January 18–20, 1940

The Twelfth Annual Meeting of the New York State Sewage Works Association was held in New York City on January 18th to 20th, 1940, with headquarters at the Hotel McAlpin. More than 300 members and guests were registered.

Lewis V. Carpenter of New York, Joseph E. Rehler of Olean, and Robert C. Wheeler of Albany were elected to the Executive Committee for a period of three years. Mr. C. George Andersen of Rockville Centre was elected President and Mr. Herbert H. Wagenhals of Syracuse Vice-President. A. S. Bedell and J. C. Brigham were reappointed for a term of one year to serve as Secretary-Treasurer and Assistant Treasurer, respectively.

The program was arranged so that the members of the Sewage Works Association were able to attend all the Wednesday and Thursday sessions of the Sanitary Engineering Division of the A. S. C. E.

And in like manner the members of the A. S. C. E. attended the technical sessions of the N. Y. S. S. W. A. on Friday and the joint inspection trip on Saturday. The joint banquet of the two groups was held on Friday night, at which Colonel John P. Hogan, President of the A. S. C. E., was guest speaker.

At the general business meeting on Friday it was noted that the Association had a paid-up membership of 583, and that four local sections each covering several counties, had now been established in the State. A resolution with reference to pending Federal legislation on stream pollution was adopted. At the technical session in the morning, a paper by Leroy Forman and R. F. Johns of the Bureau of Engineering, New Jersey State Department of Health, on "The Regulation of Stream Pollution in the Raritan River Basin by the New Jersey State Department of Health," proved most interesting, particularly in view of the anticipated inspection trip on Saturday.

At the luncheon Emblem Keys were awarded to the retiring president, N. L. Nussbaumer, and to L. L. Luther in recognition of his work in initiating the formation of local sections. Mr. C. A. Emerson, Chairman of the Federation of Sewage Works Associations, spoke briefly on the activities and future of the Federation.

At the afternoon session Dr. A. J. Fischer, of the Dorr Company, presented a paper, "Improved Sewage Clarification by Pre-Flocculation Without Chemicals," the discussion of which was opened by Harry W. Gehm of the New Jersey Agricultural Experiment Station. This was followed by a paper on "Studies in Corrosion Resistance of Metals in Sewage Treatment Plants" presented by G. L. Cox of the International Nickel Company, Inc. The discussion was opened by R. S. Burr of the American Brass Company. A. E. Griffin of the Wallace & Tiernan Company presented a paper on "Problems and Progress in the Chlorination of Sewage," which was discussed by H. A. Faber of the Chlorine Institute, and M. H. Klegerman of New York City.

On Saturday, through the courtesy of The Dorr Company, Inc., the Jeffrey Manufacturing Co., the Pacific Flush Tank Company, and the Wallace and Tiernan Co., Inc., a joint inspection trip by busses was enjoyed by some 150 persons to three sewage treatment plants in the Raritan River Basin, namely, Middlesex, New Brunswick and South River. At the latter plant the Underpinning and Foundation Company furnished a buffet luncheon. An excellent brochure prepared by William L. Sylvester, giving a description of the general situation in the Raritan River Basin and details of the three plants visited, greatly enhanced the enjoyment of the trip.

The following resolution was adopted at the meeting:

WHEREAS, there are pending before the Congress various bills providing for Federal participation and aid in stream pollution control, and

WHEREAS, the New York State Sewage Works Association is an organization of sewage works operators, sanitary engineers, and other

professional men, all particularly interested in improved public health and stream pollution abatement.

BE IT THEREFORE RESOLVED, that the New York State Sewage Works Association go on record as favoring a Federal bill which will provide for Federal participation and aid in stream pollution abatement.

BE IT FURTHER RESOLVED, that such Federal participation and aid in stream pollution abatement be provided through the U. S. P. H. S., which agency has the properly qualified personnel and extended experience during the past many years in stream pollution problems.

BE IT FURTHER RESOLVED, that the definite authority to regulate and control stream pollution abatement be left with the public health or other appropriate state agencies under the coordination and general guidance of the U. S. P. H. S.

BE IT FURTHER RESOLVED, that the Secretary be instructed to send a copy of this resolution to the proper congressional leaders.

A. S. BEDELL, *Secretary*

PRESIDENT'S REPORT FOR YEAR 1939

With Particular Reference to Recent Trends in the New York State Sewage Works Association

In a report for the year to indicate progress, if such has occurred, one must show the goal to be reached, or the starting point, or both.

It might be well first to outline the objects of the New York State Association, and then determine whether the objects are being satisfactorily accomplished. Furthermore, one must see if there are other desirable objectives which might be reached which are not now attempted, and in the final analysis decide if the membership is being so benefited in maximum numbers, and in the most effective way.

The objectives which we hope to attain as indicated by the Association activities can be summarized as follows:

(*a*) Dissemination of technical information and modern developments in sanitation to its members through convention meetings, and society publications.

(*b*) Good fellowship among its members, and fraternity between operators, engineers, professors and representatives of other branches of the sanitary field.

(*c*) Sponsor schools in which operators may receive instruction and thereby improve the quality of their services, and the operation of the plant in their charge.

(*d*) Sponsor scholarships in these schools for those operators who might not otherwise be able to attend.

(*e*) Sponsor competitions among members to stimulate research, writing, better plant operation, and invention of devices and processes.

(*f*) Educate the public in general in regard to better sanitation, through attendance at meetings by municipal officials, and legislative activities.

These activities and objectives are carried forward by an Association which ten years ago had a comparatively small membership, but now has a membership of over six hundred, and is the largest individual association of similar purpose in the world. The administration of the Association has not changed. It is in the hands of a group of officers whose personnel changes annually, an Executive Committee of nine, each member of which serves three years, and a Secretary who might be termed permanent as he has served since the beginning and acts as a point of contact and continuity from one administration to another. In recent years, the duties of this office have required the appointment of an assistant. In a large measure, the success which the Society has attained is due to the effort and foresight of the Secretary whose services we could not do without. Complete co-operation has been given by the New York State Department of Health.

There have been three convention meetings per year, one in New York and two upstate. Last year, it was decided to have only two meetings during the coming year.

An analysis of the membership discloses that only about twenty-five per cent are plant operators. I do not know what percentage of the total number operators in the State this may represent.

A casual inspection of programs for the last few years indicates that often the program, in the interest of securing good speakers on current topics, contains some non-members, many representatives of the State Department of Health and comparatively few operators of the smaller plants, except in round-table or question-box discussions.

During the last two or three years, there has been a lack of both quality and quantity in papers available from members for consideration for the Kenneth Allen Award. This partly arises from the fact that the award rules at present require that a paper to be considered must be presented at an Association meeting. Steps were taken to amend these requirements at the Executive meeting last night.

Out of a total membership of over six hundred, the attendance at the upstate conventions is about 125 to 175, and in New York somewhat larger due to the larger metropolitan membership.

These conditions lead to the same question in our Society as confronts many colleges as to their participation in sports today: Do you want an All-American team, or do you want every student to play the game?

In our case, should there be a few brilliant members who fill the principal parts, or should every member participate?

Really, the question is not so simple. We need and must have the brilliant leaders, but we also need opportunity for each individual member to take part. Only through participation can a member develop.

With the state meetings reduced to two, supplemental meeting through Sections is desirable and necessary.

Steps were taken at the Executive Meeting last night to expand the scope of committee work, and to enlarge the number of committee appointments somewhat according to geographical distribution.

Several years ago, a local section of the Association was formed on Long Island. Three years ago, the Genesee Valley Section was formed centering around Rochester and extending east to Geneva. Two years ago, the Western Section was formed, including the western counties. At this session, the Capital District Section is asking for favorable action on the approval of their by-laws, and I understand a similar request will be made at the next meeting by the group including Syracuse and Utica, the petition having been received by the Secretary too late to be properly considered now.

Most of the Sections have had three meetings of their own per year. I have been interested in the formation of the more recently formed Sections, and have taken occasion to visit and keep in touch with their activities. At the Section meetings, I have noticed several outstanding characteristics:

(*a*) There is a fairly large attendance of small plant operators, who probably would be unable to leave their jobs regularly for state-wide meetings.

(*b*) There is considerable interest by the local municipal officials where the Section meetings are held, in the Society activities, and frequently an awakening in them of the local need for more modern treatment facilities.

(*c*) The creation of a desire on the part of operators of small or obsolete plants for modern equipment and information on how to maintain a better external appearance.

(*d*) Greater participation in the meetings by operators, and a desire for information regarding Society activities, and an opportunity to participate in them.

(*e*) A desire generally by all classifications of membership to elevate the status of the sanitary operator and engineer, and to raise the level of municipal salaries for these positions.

(*f*) Information desired by operators on political diplomacy.

From this outline, it would seem that healthy local Sections would accomplish the following:

(*a*) Extend the membership.

(*b*) Give members a greater opportunity to participate in meetings and act as host to the Sections, which generally includes a high class renovation of the plant, or plants, to be inspected.

(*c*) Provide a means for the wider distribution of technical information among all classes of membership.

(*d*) Act as a training ground for speakers who would later take part in state-wide meetings.

(*e*) Aid in the improvement of plant operation by visiting plants in small places where a larger convention could never be held.

(*f*) Provide a source of enthusiasm and energy which would continually be fed into the State Society.

The establishment of these local Sections and their activities brings to light some difficulties as well as advantages. Generally a Section will want some representation or recognition in the state organization. This should be kept in mind when making committee appointments, in elections, and should be the subject of future study to see if cognizance of this should be taken in the Executive Committee membership. A step in this direction was made in the committee appointments for next year.

In conclusion, to provide the greatest good for the greatest number, the following points are offered for consideration:

(*a*) The Research Committee to interest itself in securing operating data pertaining to New York State plants, which would be of interest and value to the members, and in its work, seek the co-operation of various plant staffs and other members as may be required. In addition, present a written report each year which may be presented at a general session, and if possible printed in the SEWAGE WORKS JOURNAL. This suggestion was approved by the Executive Committee.

(*b*) Revise the Kenneth Allen Award rules so as to permit a greater number of members to qualify for consideration each year. This in no way is to be considered a letting down of the bars as to merit, but merely an opening of the door to permit larger numbers to participate. The Kenneth Allen Award Committee recommended that the rule be altered to include a paper presented by a member at any state meeting or section meeting, with certain other recommendations, all of which were approved by the Executive Committee and will be presented to you in detail by the Kenneth Allen Award Committee.

(*c*) Encourage members to write papers on topics to be presented at various meetings.

(*d*) Encourage a greater number of operators to enter the contests for the best annual operating report. Information regarding this competition to receive wider publicity. The Executive Committee authorized the award of "Honorable Mention" to be given to papers in the case of close decisions, and for which past winners would be eligible.

(*e*) Devise ways and means to elevate the status of Sewage Works Association members in their home communities. A Committee on Public Relations with geographical representation of some of our more prominent members was created by the Executive Committee which will function this year along those lines, including the active spreading of information regarding the Association activities and modern sanitation among the public, and in addition attempt to raise the social status of the members.

The ambition and goal of the Association, I believe, should be to secure as a member every sewage works operator in the State, together with a good representation from all other groups allied with the sanitation field. Such a body can then be a great power in promoting the welfare of the operator, and the benefits to health, and community good from proper sanitation.

Respectfully presented,

NEWELL L. NUSSBAUMER, *President*

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

MINUTES OF THE ANNUAL MEETING OF THE BOARD OF CONTROL

The Annual Meeting of the Board of Control of the Federation of Sewage Works Associations was held at the Hotel McAlpin, New York City, on January 18, 1940. Luncheon preceded the meeting. C. A. Emerson, Chairman, presided, and the roll call indicated representation as follows:

Present in person:

Name of Affiliate	*Represented by*
California Sewage Works Association	Charles G. Hyde
Central States Sewage Works Association	W. W. BeBerard
Federal Sewage Research Association	A. P. Miller
Federal Sewage Research Association	F. J. Maier
Iowa Wastes Disposal Association	Earle L. Waterman
Kansas Water and Sewage Works Association	Earnest Boyce
Missouri Water and Sewerage Conference	George Russell
New England Sewage Works Association	F. W. Gilcreas
New England Sewage Works Association	LeRoy W. Van Kleeck
New Jersey Sewage Conference	Willem Rudolfs
New York State Sewage Works Association	Fred T. Biele
New York State Sewage Works Association	N. L. Nussbaumer
North Carolina Sewage Works Association	W. M. Piatt
Pennsylvania Sewage Works Association	C. A. Emerson, Jr.
Pennsylvania Sewage Works Association	H. E. Moses
Member-at-Large	Wm. W. Buffum
Member-at-Large	Linn H. Enslow
Member-at-Large	Charles G. Hyde
Editor	F. W. Mohlman

Present in person, acting as proxy:

Name of Affiliate	*Represented by*
California Sewage Works Association	Alex. Bell (for A. C. Beyer)
Central States Sewage Works Association	Geo. J. Schroepfer (for J. L. Ferebee)
Dakota Water and Sewage Works Conference	A. S. Bedell (for W. W. Towne)
Iowa Wastes Disposal Association	Chas. G. Hyde (for Max Levine)
Kansas Water and Sewage Works Association	Earnest Boyce (for Robert Peart)
Maryland-Delaware Water and Sewerage Association	Morris Cohn (for Abel Wolman)
North Carolina Sewage Works Association	Wm. M. Piatt (for H. G. Baity)
Ohio Sewage Works Conference Group	F. W. Mohlman (for F. W. Jones)
Pacific Northwest Sewage Works Association	C. A. Mackmore (for John W. Cunningham)

Name of Affiliate	*Represented by*
Sewage Division, Texas Section, S. W. W. A.	Arthur D. Weston (for W. S. Mahlie)
Member-at-Large	Charles H. Eastwood (for W. J. Orchard)
Member-at-Large	C. A. Emerson (for H. W. Streeter)

The following were represented by proxy to H. E. Moses, Secretary-Treasurer:

Arizona Sewage and Water Works Association	John A. Carollo
Arizona Sewage and Water Works Association	A. L. Frick
Dakota Water and Sewage Works Conference	Lloyd K. Clark
Maryland-Delaware Water and Sewerage Association	Harry R. Hall
Missouri Water and Sewerage Conference	W. Scott Johnson
New Jersey Sewage Conference	Richard C. Smith
Oklahoma Water and Sewage Conference	W. M. Evans
Oklahoma Water and Sewage Conference	H. J. Darcey
Rocky Mountain Sewage Works Association	Chas. A. Davis
Rocky Mountain Sewage Works Association	Paul S. Fox
Sewage Division, Texas Section, S. W. W. A.	V. M. Ehlers

On motion the reading of the Minutes of the last Annual Meeting held January 20, 1939, was dispensed with, they having been published in the March, 1939, issue of SEWAGE WORKS JOURNAL.

Chairman Emerson stated that he would make no special report. He referred to the success of the Tenth Anniversary Volume and spoke briefly of matters relating to reorganization and expansion, which subject appears later in these Minutes.

The report of the Secretary-Treasurer, published elsewhere, showed continued growth during the year. The net membership totaled 2,750, as against 2,472 at the end of 1938. There was an increase of 240 in the past year. Two groups exceeded the 500 mark, New York with 583 and Central States having 511 members, respectively. Dues received by the Secretary-Treasurer amounted to $3,685.75, an increase of $371.00 over the preceding year. These were forwarded to the Business Manager, who received dues direct from eight affiliates. On motion the report was accepted.

The report which Business Manager Buffum presented showed 3,157 subscribers as of December 31, 1939 (2,888 in 1938), divided into 2,744 members and 413 non-members. The cost of printing and mailing SEWAGE WORKS JOURNAL was $2.88 per subscriber ($3.07 in 1938), a total cost of $9,221.93. Profit for 1939 was $288.39, this figure for 1938 being $147.52. Advertising income was $6,626.49, there being nine pages more of advertising than last year.

The figures, not included above, for the sale of the Tenth Anniversary Volume (Modern Sewage Disposal), as given by Mr. Buffum, were highly gratifying. 2,500 copies were purchased, of which 1,787 copies have been sold, 124 copies distributed gratis, with 589 copies yet on hand to be sold. A net profit of $810.58 has been made. Mr.

Buffum anticipates the sale of the remaining copies. This report was by motion accepted with the thanks of the Board for the excellent service given.

In the matter of appreciation, the Secretary-Treasurer informed the Board that he had received a telegram from Secretary Kepner of the Rocky Mountain Sewage Works Association which, inter alia, stated "We are sending to Mr. Buffum's office a Bronze Plaque in appreciation of his services."

Dr. Mohlman, Editor, in his report presented an interesting classification of subject matter printed in SEWAGE WORKS JOURNAL. For the years 1936–1939 inclusive, he showed the number of pages published in each issue under the following headings: Sewage Research, Plant Operation, Industrial Wastes, Stream Pollution, Operators' Reports and Reviews and Abstracts. He pointed out the effort made to make the JOURNAL of practical value to the plant operator, which is a cardinal principle in the Federation's policy, and to that end, with the valuable aid of Dr. Hatfield, much space is being given to papers on Plant Operation and Operators' Reports. These subjects together with Sewage Research occupy 75 per cent of all subject matter. 30 per cent of all papers are received direct from authors and 70 per cent by way of the affiliates. In accepting his report the Board expressed its appreciation of the valuable service of Dr. Mohlman.

Mr. Emerson made a brief report on behalf of F. W. Jones concerning the progress of the Joint Committee for Nomenclature for Sewage and Sewage Treatment.

It was moved and seconded that the Board of Control commend the New York State Sewage Works Association for its accomplishments during the past year and extend its best wishes for its continued growth and service in the field of sewage treatment. Motion carried.

The Board was informed of revisions in the Constitution and By-Laws of the California Sewage Works Association. These conform to the requirements of the Federation.

Chairman Emerson, under the subject of Expansion and Reorganization, explained that the Board at the January 1939 meeting authorized the appointment of a committee to consider methods for strengthening the Federation and to provide some plan for its further development. Such a committee was appointed and he presented to the Board its Progress Report, which was thereafter the subject of extended discussion. This report, with some slight modification made by a majority of the Committee present at the Board meeting, was accepted by the Board. By motion it was ordered that this report should appear verbatim in the next issue of SEWAGE WORKS JOURNAL.

It was further moved and seconded that the Chairman be authorized to continue the Committee with replacement of those not accepting service, said Committee to submit a final report within 90 days—Carried.

A subject allied with the foregoing relates to holding some form of National Convention. This was discussed, and it was represented that

there was a rather insistent demand for such a meeting. Mr. Emerson noted that there was nothing in the Constitution and By-Laws to prohibit such a meeting. Finally it was moved and seconded, the motion carrying, that a Convention Committee be appointed to arrange for a Federation Convention to be held within a year in conjunction with the meeting of some member association. Also, the Executive Committee was authorized to make an appropriation for the preliminary expenses of this committee not to exceed $50.00.

The Budget of 1939 was made the basis of that for 1940 and it was suggested that it be adhered to as closely as possible; this by motion, seconded and passed.

It was moved, seconded and carried that the present officers, where eligible, be continued in office. Accordingly, the officers are as follows, term of office for 1940 except as noted:

Officers

Chairman, C. A. Emerson, New York
Vice-Chairman, Linn H. Enslow, New York
Secretary-Treasurer, H. E. Moses, Harrisburg, Pa. (2 years)
Business Manager, Wm. W. Buffum, New York
Editor, F. W. Mohlman, Chicago, Ill.
(Term of Editor expires in 1942)

Members-at-Large

Wm. W. Buffum, New York
Linn H. Enslow, New York
Charles G. Hyde, Berkeley, Cal.
Wm. J. Orchard, Newark, N. J.
H. W. Streeter, Cincinnati, Ohio

It was moved and seconded, motion carried, that the Executive Committee select the members of the Constitutional Committees. These comprise Executive, Membership and Publication Committees.

The Board adjourned at 4:20 P.M.

Respectfully submitted,

H. E. Moses,
Secretary-Treasurer

(*Editor's Note:* For preliminary reports on the meeting, see January, 1940, issue of Sewage Works Journal.)

REPORT OF SECRETARY-TREASURER FEDERATION OF SEWAGE WORKS ASSOCIATIONS FOR THE YEAR ENDING DECEMBER 31, 1939

The year 1939 was one of continued growth of the Federation. No new affiliates joined, but there was a substantial increase in membership. Correspondence was had with several persons inquiring as to

the procedure to be followed to unite with the Federation, which may be productive of results later.

Interest in the annual meetings of the affiliates continues unabated judging from reports received by the Secretary or published in SEWAGE WORKS JOURNAL and other engineering periodicals. Many indicate increased attendance. In some of the larger state groups or in Affiliates comprising more than one state it has become the practice to hold sectional group meetings in addition to the Annual Conference. This tends to sustain interest during the year and is convenient for the members residing in a given section. The meetings usually are for one day only and generally include inspection of the local plant.

At the close of 1939 there was a gross membership of 2,804; with a deduction of 54 dual memberships, leaving a net total of 2,750, or an increase of 240 in the past year.

	Gross Mem's'p	Dual Mems.	Gross New Mems. and Reinstatem'ts	Did not Renew Sub. 1939	Membership	
					Incr.	Decr.
Arizona S. and W. W. Ass'n	26	—	11	11	—	—
California S. Wks. Ass'n	264	1	40	32	8	—
Cent. States S. Wks. Ass'n	511	8	138	57	81	—
Dak. W. and Sew. Wks. Conf.						
North Dakota	16	—	5	1	4	—
South Dakota	28	—	11	7	4	—
Federal S. Research Ass'n	60	—	9	3	6	—
Ga. W. and Sew. Ass'n	28	—	14	9	5	—
Iowa Wastes Disp. Ass'n	34	—	4	15	—	11
Kansas W. and S. Wks. Ass'n	35	—	17	9	8	—
Md.-Del. W. and S. Ass'n	25	—	4	7	—	3
Michigan S. Wks. Ass'n	148	1	62	12	50	—
Missouri W. and S. Conf.	18	—	9	20	—	11
New England S. Wks. Ass'n	167	8	24	14	10	—
New Jersey Sew. Conf. Group	61	—	8	10	—	2
N. Y. State S. Wks. Ass'n	583	25	121	83	38	—
N. Carolina S. Wks. Ass'n	71	—	25	9	16	—
Ohio S. Wks. Conf. Group	110	—	10	7	3	—
Oklahoma W. and S. Conf.	4	—	4	—	4	—
Pacific N.W. S. Wks. Ass'n	65	1	30	14	16	—
Pennsylvania S. Wks. Ass'n	201	8	36	27	9	—
Rocky Mt. Sew. Wks. Ass'n	35	—	12	6	6	—
San. Engr. Div. of the Arg. Society of Engrs.	12	—	2	—	2	—
Sew. Div.-Tx. Sec., S. W. W. A.	25	—	13	13	—	—
Can. Inst. on Sew. and San.	123	2	13	11	2	—
Inst. of Sew. Purif.—Eng.	109	—	21	20	1	—
Inst'n of San. Engrs.—Eng.	50	—	5	6	—	1
	2804 −54	54	647	407	268 −28	28
	2750 Net Mems.				240 Incr.	

Membership was not renewed by 407, which was 53 less than the preceding year. This shows an improvement, but this loss seems too large, being 15 per cent of the year's net membership. The membership details are shown in the table on page 381.

Dues received by the Secretary-Treasurer and forwarded to Mr. Buffum amounted to $3,685.75, or $371.00 more than for the preceding year. The petty cash account of the Secretary-Treasurer for stamps and miscellaneous office expenses amounted to $21.55. Details of dues received appear below:

	For 1938	For 1939	For 1940	Total	Refund
Arizona S. and W. Wks. Ass'n	(Paid dues direct to Mr. Buffum)				
California S. Wks. Ass'n	$ 7.50	$ 401.50		$ 409.00	$ 1.50
Cent. States S. Wks. Ass'n		757.75		757.75	1.50
Dak. W. and Sew. Ass'n		61.50	$ 9.00	70.50	
Federal Sew. Research Ass'n		90.00		90.00	
Ga. W. and Sew. Ass'n	(Paid dues direct to Mr. Buffum)				
Iowa Wastes Disp. Ass'n	1.50	25.50	6.00	33.00	
Kansas W. and S. Wks. Ass'n		54.00		54.00	
Md.-Del. W. and S. Ass'n		37.50		37.50	
Michigan S. Wks. Ass'n	1.50	222.00		223.50	1.50
Missouri W. and S. Conf.	(Paid dues direct to Mr. Buffum)				
New England S. Wks. Ass'n	12.00	240.00		252.00	
New Jersey Sew. Conf. Group		90.00		90.00	
N. Y. State S. Wks. Ass'n	18.00	832.50		850.50	6.00
N. Carolina S. Wks. Ass'n		106.50		106.50	
Ohio S. Wks. Conf. Group		165.00		165.00	
Oklahoma W. and S. Conf.	(Paid dues direct to Mr. Buffum)				
Pacific N.W. S. Wks. Ass'n	(Paid dues direct to Mr. Buffum)				
Pennsylvania S. Wks. Ass'n		292.50		292.50	3.00
Rocky Mt. Sew. Wks. Ass'n		39.00		39.00	
San. Engr. Div. of the Arg. Society of Engrs.	(Paid dues direct to Mr. Buffum)				
Sew. Div.-Tx. Sec., S. W. W. A.	1.50	36.00	1.50	39.00	
The Can. Inst. on Sew. and San.		176.00		176.00	
The Inst. of Sew. Purif.—Eng.	(Paid dues direct to Mr. Buffum)				
The Inst'n of San. Engrs.—Eng.	(Paid dues direct to Mr. Buffum)				
	$42.00	$3627.25	$16.50	$3685.75	$13.50

The reception given to the Tenth Anniversary Volume is gratifying to those instrumental in its conception and production. Mr. Buffum reports the sale has exceeded expectations, and from many sources laudatory comments have been received.

H. E. Moses,
Secretary-Treasurer

Reviews and Abstracts

PLANNED PROGRESS IN POLLUTION CONTROL

Incodel, Bull. 3, Series B (Jan., 1940)

The interstate commission on the Delaware River Basin (Incodel) was organized in 1936 by the Joint Legislation Commission on Interstate Co-operation of Delaware, New Jersey, New York and Pennsylvania. It is engaged in the formulation and execution of a co-ordinated, unified plan looking toward the wise use, development, and control of the resources of the Delaware Basin as a whole. In the basin three-fourths of the population is directly affected by the degree of pollution to which the river is subjected. No municipality and no state in this watershed is immune. With the exception of the smaller and more homogeneous Hudson Bay area, no comparable interstate plan for the correction and control of water pollution has been devised for any drainage basin in the nation.

In the past three years (1936–1939) $10,580,000 has been spent in the construction of sewage collection and treatment works (N. J., $3,052,000; Pa., $7,528,000). The present population served by the improvements is 282,500 (Pa., 219,500; N. J., 63,000). Approximately 90 per cent of the work done was accomplished with the use of federal funds as grants-in aids, or loans, or both. More than 80 per cent of the over 5 million people living in the basin have sewerage systems; the sewage of nearly two-thirds of the population is discharged in the Delaware river without treatment; the volume of domestic sewage is estimated at 500 m.g.d. Of this amount, 75 per cent is contributed by Pennsylvania, 20 per cent by New Jersey, with Delaware and New York producing about 5 per cent. Of the 128 incorporated municipalities in the basin with more than 2,500 population, 110 have public sewers and 67 treatment plants, treating about 36 per cent of the total volume of sewage before discharge into the river.

The Philadelphia-Camden area is mainly responsible for the pollution and the reputation as the most grossly polluted area in the nation. At the present time almost 80 per cent of Philadelphia's sewage is discharged raw into the river. With Philadelphia drawing half of its water supply from this source, it follows that no other large city in the nation has an equivalent polluted source of domestic water supply. The cost for the abatement of municipal waste pollution is estimated at $65,000,000. This estimate does not include treatment of all municipal or industrial wastes.

WILLEM RUDOLFS

THE CITY'S SEWAGE GOES TO SEA

BY N. A. BOWERS

Eng. News Record, 123, 689–691, 764–766, 846–848 (1939)

This article presents a summary of data and information concerning the design, construction and maintenance of outfall sewers with submerged discharge into large bodies of water, particularly the oceans.

Ocean disposal of sewage is usually closely regulated by State Health authorities. The California State Board of Health uses the following relationship in deciding upon the length of ocean outfalls necessary to keep the beaches free of sleek menace or undue bacterial contamination, where free dispersion of the sewage takes place.

Tributary Population	Sleek Field in Acres per 1,000 Pop.
10,000	8.0
25,000	6.0
50,000	5.5
100,000	4.5
1,000,000	1.0

The fundamental requirements in outfall design are: (1) provision for conveying a stipulated quantity of sewage flow to a point of discharge far enough from the shore line, under the conditions existing at the site, to prevent nuisances that will be condemned by health authorities; a type of construction that will give the sewer long life, low operating and maintenance costs, and possibility of extensions such as may logically be expected later.

The choice of locations of a subaqueous outfall sewer depends on many factors. First come the sanitary regulations mentioned above. The kind and quality of the material constituting the ocean bottom and the bottom topography must be considered. Water depth, the strength and direction of littoral currents and distance from recreational beaches and residential areas must be studied. Possible damage to the sewer from dragging anchors is always a potential risk for which provision should be made.

Wave action is particularly important in causing pipe movement and breakage of joints. The zone in which the waves break has the greatest effect on the pipe, caused by wave impact and bottom scour. The changes in pressure head may force sand into the line through the joints. Authorities believe that at depths greater than 35 feet conditions are fairly stable and the dangers of pipe movement are practically eliminated, except in the case where littoral currents are strong.

Records of currents along beaches should be available for periods extending over a year in order to take account of all seasonal variations. Although currents are an asset in dispersion, they may have the adverse effect on the foundation if the bottom is soft.

The type of outfall sewers to be used depends on the size of pipe required. The practice has been to consider outfall sewers of 18 in. and smaller sizes in one category and sizes of 20 in. or above in another. Construction methods are appreciably different in the two categories.

For sizes under 18 in. the advantages of all-metal pipe are such that it is universally accepted. Wrought iron pipe sections connected with threaded couplings are frequently used. Cast iron pipe with bell and spigot joints provides a durable line. In some instances a continuously welded pipe with welded joints has found favor. Experience gained by the oil companies in California, Mexico and Persia on subaqueous oil lines for loading tankers offshore has been used to advantage by engineers on sewer outfalls.

The materials for sizes above 18 in. are usually cast iron or concrete. Cast iron pipe may have the bell and spigot joint or the more expensive ball and spigot joints. However, the new White's Point outfall in California was made of a reinforced concrete pipe barrel with a cast iron joint of the ball and socket type. Concrete pipe can be used in much larger sizes than cast iron. The sections may be cast near the site of operations. The casting yard problems frequently determine the length of the section which may be used.

Joints between sections of pipe in an outfall sewer appear so frequently in the list of troubles as to make them the most vulnerable part of the installation. The smaller diameter pipes below 18 in. do not cause much difficulty as the joints may be made as strong as the pipe itself. Sections are comparatively long and fewer joints are required. For the larger pipes it is common to connect a number of lengths on shore, using bell and spigot joints and a strong and durable jointing material. If the jointing compound is a mastic or plastic material, the temperature effect of the relatively warm sewage must be considered. Sewage temperature may be high enough to soften the compound, weaken the bond and permit the pulsation of wave action eventually to work the mastic loose and open the joint. Instances of serious damage from this cause are on record.

The submarine joints may be of the ball and socket type or bell and spigot. With the latter, the calking should be done by a diver working on the inside of the pipe. The diver will find it easier to work on the inside as he will not be swayed by the waves and will not have to cut bell holes in the foundation in order to calk. Experience has shown that submarine joints should be placed at intervals of 5 to 10 sections to give the necessary flexibility to take up any horizontal or vertical movement in the line. They will also reduce the tendency to pull apart the rigid joints or to partially open them.

Outlet structures at the discharge end of the pipe are of particular importance where maximum dispersion must be obtained in relatively shallow water. The simplest form of terminal is merely the open end of the pipe with the end turned up to prevent the entrance of sand. Openings in the top of the pipe may be used. Where the line is divided to form two outlets discharging in different directions, care must be taken in the hydraulic design so that each branch will carry the same flow in order to prevent clogging of one line. Diffuser caps have been found to give excellent results when properly designed.

In laying the outfall sewer the line is preferably placed in a trench cut in rock and covered with concrete in the zone where the waves break. Trenches cut in the sand are not acceptable as it is difficult to excavate for a smooth bottom. Undue joint stresses may result. Backfilling with sand is looked upon with disfavor as joints may leak slightly and sand may be sucked in by wave pulsations.

Seaward from the breaker line preference is given to a line simply laid on the ocean bottom. Where the bottom is not uniform or where swift currents cause a shifting of the bottom, it may be necessary to use trestles. Timber trestles are considered safer than steel because collision may damage a large section of the steel structure firmly tied together while only a small part of the timber trestle will fail, causing less pipe breakage and easier repairs.

Anchorages may also be required. For smaller pipes chains may be attached to collars placed at 50 to 100 ft. intervals. Old iron chains about 25 ft. long are laid on the bottom at right angles to the pipe. The weight of the chains soon imbeds them far enough to give the outfall resistance to transverse movement. On hard bottom or where ocean currents prevail, a preferred method of anchorage is the use of concrete piers, either poured in forms or placed in sacks piled up around the pipe.

Subaqueous outfalls of diameters under 18 in. ordinarily are constructed on shore and then placed in one operation, either by pulling the line along the ocean bottom or by launching, towing to place and there sinking it bodily. A preferred method is first to construct an inclined slide or runway on the beach on which the pipe sections are assembled and the joints are made tight.

Placement of outfalls of larger diameter is either made by lowering the sections from a trestle or derrick barge or with the aid of pontoons, or a combination of both. Divers are essential to direct the work.

Considerable maintenance work is necessary in outfall sewers to keep them in serviceable condition. Submerged manholes should be installed 300 to 500 ft. apart so that divers may enter the line occasionally. Their function is to note any settlement in the line and whether the joints are tight. They frequently calk joints and perform minor repairs. Inspection will also indicate the accumulation of sand or grease which might reduce the capacity of the outfall.

The author presents a table of statistics and cost data on some typical subaqueous outfall sewers and comments on the length of life of the various materials in use. Cast iron seems to have an indefinite length of life in sea water. Wrought iron has stood up well for small sewers and may have strong welded joints. Steel pipe has the advantage of lower cost but does not have long life unless coated and secured by a cathodic protection device to prevent electrolytic corrosion. Large diameter outfalls require frequent servicing, no matter what the material.

ROLF ELIASSEN

SEWAGE DISPOSAL PROJECT OF BUFFALO, NEW YORK

By Samuel A. Greeley

Proc. A. S. C. E., 65, 1341 (October, 1939)

The purpose of this paper is to present some of the engineering data accumulated during the design and construction of the sewage disposal project of Buffalo, N. Y. During the three years 1936 to 1939 the Buffalo Sewer Authority completed the construction of intercepting sewers, sewage treatment works, and storm-water relief sewers, at a total project cost of $15,000,000.

The first investigation of the sewage disposal problem of Buffalo was made between 1909 and 1918 by the International Joint Commission in connection with the pollution of the boundary waters between the United States and Canada. In 1934 the New York State Department of Health issued orders requiring that treatment works be completed and in operation by October, 1937.

The function of the project is to relieve Buffalo and Black Rock Harbors and Buffalo River from undue pollution, to remove contamination from the Niagara River and to reduce the bacterial content of its waters in order to avoid placing a heavy load on the communities below Buffalo which derive their water supply from the Niagara River. The drainage area of the Niagara River at the outlet of Lake Erie is about 175,000 sq. miles. The average discharge is 203,000 c.f.s., with 176,000 c.f.s. exceeded 90 per cent of the time. The minimum monthly average discharge on record is 142,000 c.f.s. and the maximum is 251,000 c.f.s. Thus the discharge is relatively large and uniform throughout all of the year. Below Buffalo the Niagara River is used as a water supply by Tonawanda, North Tonawanda, Lockport, Niagara Falls, Youngstown, and Fort Niagara in New York, with a total population of about 150,000, and by the cities of Fort Erie and Niagara Falls in Canada.

Practically all of the sewers of Buffalo are on the combined plan, their total length being about 710 miles. The first sewers were built prior to 1850. Before their construction of the intercepting sewer there were 62 outlets, all of which have now been connected to the interceptor. The city is divided topographically into two parts, one draining naturally to the Buffalo River and the other directly to Black Rock Harbor and the Niagara River. With a few exceptions, the main drainage system has been developed along these natural lines. Black Rock Harbor is a waterway connecting the New York State Barge Canal with Buffalo Harbor. Only a small flow, about 100 c.f.s., is maintained from the locks. About 40 c.f.s., or 20 per cent of the entire sewage of the city, emptied into this harbor, making it grossly polluted. Conditions in the Buffalo River were also critical. Samples taken during the summer of 1937 showed no dissolved oxygen in the stream for a length of 5 miles from its mouth, and a B.O.D. as high as 40 p.p.m.

Much field engineering work was required to be done promptly, including surveys for design and for the acquisition of land and rights of way, investigations of the best location for intercepting sewers, the supervision of borings, examination and gaging of existing sewers, and planning and organizing a laboratory. Much useful work was accomplished through the laboratory, in determining sewage characteristics and quantities and the condition of the water in many of the waterways. Tables and graphs are included by the author to indicate the results of the laboratory work. During 1936 investigations were made as to the effect of storms on the quantity of suspended solids in the sewage, with special attention being paid to the characteristics of the first flushings which would be taken to the treatment plant.

Buffalo has a relatively large number of industries which produce sewage. Many of these are situated in the southerly part of the city which drains naturally to the Buffalo River. Some of the larger plants discharge directly into the river and do not use the sewers. The chemical industries form an important group, including seven major plants. Two large coal coking plants, 24 packinghouses, 11 breweries, 15 dairies, 8 oil handling and refining plants, five rubber reclaiming plants, and five tanneries are included. Many of these industrial establishments have been surveyed and the quanti-

ties and characteristics of the wastes determined by gagings and analyses. Some of the sewage from the industries is not likely to be amenable to treatment. It has thus been desirable to undertake a co-operative program with the industries for the removal of pollution from the Buffalo River and from the sewers of the city. This program has proceeded on a satisfactory basis.

Stormwater relief sewers were planned to serve the Bird Avenue sewer district which has an area of 5,490 acres. The main sewer for this district was inadequate throughout its length. The new sewers were designed on the basis of the rate of rainfall estimated to occur once in ten years. A runoff coefficient of 0.60 was used for the area within the city limits and 0.22 for the rural areas outside of Buffalo. The size of relief sewers ranged from 3.5 to 12.0 ft. in diameter. The total cost of these amounted to $2,330,000.

Intercepting sewers were designed to serve a future population of 1,100,000, expected to be reached in 1985. The present population is about 670,000. For the design of sewers and structures serving only part of the city, the estimated average sewage quantities were increased by factors to allow for a different distribution of the future growth than that estimated. The factors varied with the size of the area served and with the estimated density of population, having a maximum value of 1.5. These factors were applied to the domestic, industrial, and commercial quantities, but not to the infiltration. For the area that will overflow to the Buffalo River the intercepting sewer capacities were based on 3.0 times the estimated 1985 average flow, and for all other areas on 2.5 times the 1985 flow. Kutter's formula, with $n = 0.013$, was used in determining the capacities of all intereceptors. Tables showing basic factors and computations for determining the flows are presented. Typical sewer sections for use in all types of excavations are also given, as is a profile of the main line.

Many special structures were required. The South Buffalo pumping station was constructed and equipped with four vertical centrifugal pumps having a total rated capacity of 100 M.G.D. A tunnel crossing under the Buffalo River leads to the station through two conduits, one 36 in. in diameter and the other a rectangular section 4 ft. by 6.5 ft. The main crossing under Black Rock Harbor to the sewage treatment plant comprises two conduits, each 8 ft. in diameter. Some 55 intercepting and regulating chambers were built, as well as large number of special structures including creek and sewer crossings, junction chambers, and several lateral separate sewers. The estimated final construction cost of the intercepting sewers was $6,407,000. The cost of sewers in dollars per linear foot for the various types of sections is included in a table.

The sewage treatment plant was constructed on Bird Island, along the west boundary of the city and somewhat north of the east and west center line of Buffalo. The Authority had to obtain special permission from the City of Buffalo, the State of New York, and the United States for the use of this site. The bases of design are presented in an extended table. The following is a brief summary of these factors:

Design Population (1950)	750,000
Design Flow—Average	150 M.G.D.
Sewage Characteristics	
Suspended Solids	150 p.p.m.
Pounds per Cap. per Day	0.3
Volatile Matter	70%
Grit, Cu. Yd. per M.G.	0.15 average
	1.0 max. 24 hr.

The sewage treatment plant occupies a somewhat triangular shaped site having an area of 23.0 acres. The author presents a general plan and a hydraulic profile of the plant. The sewage is first pumped, then flows by gravity through a screen and grit chamber, venturi meters, aerated channels, four sedimentation tanks, and a submerged outfall to the Niagara River.

The pumping building contains six vertical, close-coupled, centrifugal pumps, each with a rated capacity of 100 M.G.D. The average pumping head is 23 ft. Two of the pumps have two-speed motors to assist in uniform regulation of flow into the sedimen-

tation tanks. There are twelve grit chambers. Each pair operates as a unit with one bar screen and pump, with no cross-connections between these units. Coarse trash racks with bar spacing of 5.5 in. precede mechanically cleaned bar screens with a clear spacing of 0.75 in. Two venturi tubes follow the grit chambers, after which two conduits, each 285 ft. long, are used for aeration of the sewage. Chlorine is added at the effluent end of the conduits. The sewage then flows through a by-pass and control chamber to four circular clarifiers which provide a detention of 80 min. at average flow. Each of these tanks is 160 ft. in diameter. Effluent from these flows into the Niagara River about 200 ft. from shore at a depth of 40 ft.

The settled sludge is pumped to four sludge storage tanks, each 90 ft. in diameter and equipped with a floating cover. These have a total capacity of 750,000 cu. ft. or 1.0 cu. ft. per capita. In the center of the space occupied by these tanks is a building that houses sludge pumping and control equipment, with provision for the delivery of sludge at given rates into one or all of the four tanks, the transfer of sludge from one tank to another, and to the sludge disposal building. This building houses three vacuum filters, three flash-type sludge incinerators, and the boiler plant for heating the sludge storage tanks and all the buildings.

Each filter is 11.5 ft. in diameter and 14 ft. long, with a filtering area of 500 sq. ft. It is estimated that these filters will dewater the sludge from a moisture content of 94 per cent to 70 per cent at an average rate of 5 lb. of dry solids per sq. ft. per hour when conditioned with 2.0 per cent ferric chloride and 8 per cent lime. The sludge cake discharges on a belt conveyor which leads to a mixer where the wet cake is mixed with previously dried sludge. The mixture is delivered to the flash driers; thence it is blown into the furnaces for combustion. Any deficiency in heat units in the sludge is made up by burning oil or gas. The incinerators include ash-removal equipment, fly-ash cyclones, and other appurtenances. Each of the three incinerators has a rated capacity of 100 tons of sludge cake containing 70 per cent moisture per 24 hrs. Two of the units will probably be sufficient to dispose of the average quantity of sludge.

The various units of the sewage treatment plant are connected by a service tunnel along one side of which the main ventilating duct is constructed. Where sewage is exposed in any building large ventilating fans are provided which withdraw air and discharge it into the main duct which in turn leads to the 175 ft. chimney. The main building houses the office and laboratory, garage, machine shops, blowers for the aerated conduits, chlorine equipment, and the plant water supply, including pumps and elevated tank. The cost of the main sewage pumping station and treatment plant was $4,378,891. The part of this total sum required for sewage treatment is about $3,500,000, which is equivalent to $4.67 per capita or $23,000 per M.G.D. of design capacity. A summary of bids and allocations of cost are presented.

Under the act creating it, the Buffalo Sewer Authority has taken over the maintenance and operation of all the sewers of the city. Thus, estimates of annual operating costs include items for the maintenance of lateral sewers, for cleaning and repairs, and for progressive rehabilitation. This amounts to approximately $1,500,000 per year, including debt service, of which $397,000 is for the maintenance and operation of the sewage treatment plant. The Authority has adopted a two-part schedule for raising the annual revenue. The schedule provides that 55 per cent of the total sum (or $825,000) shall be derived from a charge based on water consumption, and that all of the remainder (or $675,000 per yr.) shall be derived from a charge to be paid by all taxable property in proportion to the assessed valuation. The portion of the rate applicable to water use is 40 per cent of the water rates, and the portion applicable to assessed valuation is about $0.73 per $1,000.

ROLF ELIASSEN

PROBLEMS AND TRENDS IN ACTIVATED SLUDGE PRACTICE

By Robert T. Regester

Proc. A. S. C. E., 65, 1501 (November, 1939)

This paper discusses the problems presented in the design and operation of activated sludge plants in the United States and trends indicative of American practice since 1930. Pertinent data relating to the basic design and principal characteristics of thirty plants of large and medium capacities are included for comparative study. Available operation results for certain works are also given. The total nominal capacity of the activated sludge plants in this country is estimated at about 1,700 M.G.D.

Preliminary treatment is generally required. Mechanically cleaned bar screens are installed in most plants. When combined sewage is treated grit chambers are usually included. Primary sedimentation is provided to even out the flow, to aid digestion and reduce the volume of the excess activated sludge, and to reduce the quantity of air consumed. Pre-chlorination may be used for odor control.

The design of aeration tanks has undergone a marked change in recent years. Aeration periods have decreased to the extent that some large plants are now using only 3 to 3.5 hours. In some instances diffuser plates of baffles have been arranged in occasional rows across the tank to break up the core of spiral flow and thus lessen short-circuiting. "Tapered" aeration is being tried out in several plants to supply air in accordance with the oxygen demand curve. This may be arranged by decreasing the percentage of diffuser plate area along the tank. At the Tallmans Island plant in New York the same purpose is accomplished by introducing settled sewage at three points in the tank.

Operating galleries extending over the full width of a battery of aeration tanks, located between these tanks and the final clarifiers, are usually provided in the larger plants. The gallery contains the air main, return sludge pipes, settled sewage conduit, control valves, drains, and all metering devices. Regulation of flow is accomplished by hydraulically operated valves in the venturi meter tubes and the air pipes. Cone valves are sometimes used in conjunction with venturi meters to control the rate of flow. There is a definite trend toward the accurate proportioning of flow to the various units of the plant.

Return sludge pumping is almost universally accomplished by centrifugal pumps although air lifts have been used. To provide for the necessary variations in the rate of returning sludge, variable-speed pumps are required up to a maximum capacity equal to 50 per cent of the average sewage flow.

Air blowers in use are of two general types—rotary positive-displacement and centrifugal. Flexibility for efficient operation over a wide range of total air capacity is often provided by having units of different capacities. Since power cost for air blowing is a major part of the total operating cost of an activated sludge plant, increased attention has been directed to the selection of blower capacities. Rotary compressors are generally used in the smaller plants and are particularly adaptable to being driven by gas engines as both must operate at low speeds.

In the larger plants the centrifugal type, driven by motors or steam turbines, has been used. Motors may be of the induction or synchronous type. The latter provides for power-factor correction but requires elaborate electrical control equipment. Centrifugal blowers, like centrifugal pumps, operate most efficiently at one point on the pressure-volume characteristic curve. For a proposed installation it is necessary to select the sizes of blowers with proper regard for the probable air requirements—minimum, average, and maximum—to secure an economical arrangement. Certain new features of centrifugal blower installations consist of: independent structural supports for the blower units separated from adjacent parts of the blower building by elastic joint material; flexible joints in connecting pipes; cone-type check valves automatically operated; air blow-off valves for either the air discharge manifold or the discharge pipe of each blower.

The final sedimentation of the mixed liquor is an essential step in the activated sludge process which deserves particular attention. A lowering of the overflow rate down to 900 to 1,000 gal. per sq. ft. per day on the basis of average mixed liquor flow has been practiced in the latest of designs. Detention periods range from 1.7 to 2.6 hours. The shape of the tanks is generally circular or rectangular, although square or octaganal areas have been used. Effluent weirs for circular tanks are placed around the periphery. Rectangular tanks are provided with numerous transverse and longitudinal arrangements of weirs to give the maximum weir length and thus reduce the rising velocity. Values from 8 to 33 sq. ft. of tank area per linear foot of weir are in use.

Probably no other branch of activated sludge practice has shown more divergent trends than methods of sludge disposal. The most common method in smaller plants has been the return of waste sludge to the preliminary settling tanks, with subsequent digestion of the combined sludge. The use of gas from the digesters to run gas engines connected to compressors is common practice. Concentration of the sludge in separate tanks, either of the Dortmund-type or with a picket-fence mechanism, is in use in some of the larger plants. Centrifuges have been installed in two plants for the concentration of activated sludge. Vacuum filtration and drying of sludge for sale as a fertilizer takes place in several plants. Rotary driers are used in older installations while "flash"-drying has found favor lately. Incineration is also utilized at several large plants. The author presents a table showing ultimate disposal of the sludge.

Further treatment is occasionally given to the effluent from an activated sludge plant. Chlorination may be used seasonally for sterilization. Where extra head is available cascades have been arranged to affect additional oxidation. Magnetite filters have been installed at several plants to assure a clear effluent at all times.

The operation of activated sludge plants and the control of the process have presented a variety of problems. Starting procedure for smaller plants has been to fill the aeration tank with freshly settled sewage and aerate for a period, then to settle the aerated sewage and mix the sludge with more incoming material, repeating the operation until a biologically active sludge is developed. This may require from one to three weeks.

Control of the process is largely a matter of laboratory procedure. In many cases this has been simplified to the extent that the shift operators can perform the tests, thus reducing the time element and permitting corrective steps to be taken when necessary. Valuable criteria of performance are the suspended solids in the mixed liquor, the dissolved oxygen in the liquid of both the aeration and final settling tanks, and the sludge index. The optimum suspended solids content of the mixed liquor is best determined by actual plant performance. It is related to the character of the sewage to be treated, the quantity of air introduced, the detention period, and possibly other factors. Curves are presented to show the relationship between the suspended solids in the mixed liquor, the solids in the return sludge and the rate of sludge returned. The maintenance of dissolved oxygen in the effluents of both the aeration and final settling tanks, to the extent of at least 2 p.p.m., is recognized as a necessity for proper operation. The sludge index in the mixed liquor is used principally as a means of detecting the probability of bulking sludge. The depth of sludge blanket maintained in the final tanks may have a detrimental effect upon the quality of the sludge unless the level and quantity stored is kept to a minimum consistent with plant requirements and density of sludge desired. A high level may also cause passage of floc with the effluent.

Certain influences may have a harmful effect upon the satisfactory performance of activated sludge plants. Some of these factors are: septic raw sewage; variations in the quantity and strength of the incoming sewage; the return of strong supernatant liquid from digestion tanks to the sewage ahead of preliminary sedimentation; and relatively large proportions of industrial wastes in the sewage. The process has been used successfully for treating sewage containing appreciable quantities of wastes from packing houses, vegetable canneries, rayon mills, and other sources. On the other hand, wastes from metal works, dairies, textile mills, and diverse industries have proved troublesome, and in some cases have been found impossible to treat by this process.

The perplexing character of many problems encountered in practice, together with

the desire for a more complete understanding of the fundamental phenomena and the environmental factors of the activated sludge process, has stimulated research in this field. Much progress has already been made by numerous investigators. The author lists fifteen phases which need further investigation in order to lead toward standardization and a more complete understanding of the process. These include the influence of basic factors such as the character of sewage, variation in flow, and the degree of pre-treatment upon plant performance, the object being to determine design limits; the effects of certain industrial wastes; the handling of supernatant liquor; sludge thickening; studies of air and diffuser equipment, the efficiency of final settling tanks, and control tests.

ROLF ELIASSEN

STUDIES ON THE DIGESTION AND DISTILLATION OF ORGANIC WASTES I, II, III, IV, V, VI

BY S. SHIBATA

Soc. Chem. Ind. Japan, **42**, 38, 79 and 164 (1939)

Waste activated sludge when mixed with well digested sludge produced, during the course of 60 days, 225–325 each of gas per gram volatile solids added and resulted in 41.3 per cent reduction of volatile solids. During the first 20-day period high percentages of hydrogen were found in the gases (15–30 per cent). The digested residue when subjected to dry distillation (at 500° C.) yielded from 10–15 per cent of crude oil on the basis of dry weight of the sludge. About 70 per cent of the material was recovered as retort residue (Shokatan) the balance being recovered as ammonia liquor and lost as gas. The crude oil was high in carbon and hydrogen while the Shokatan was low in these elements and high in ash. Specific gravity of the crude oil was 0.912–0.922. Digested settling tank sludge yielded only 7–10 per cent of crude oil. Activated sludge, with a lower yield of gas, gave a higher yield of crude oil than digested settled solids. Of two activated sludges the one producing the greater quantity of gas gave a smaller yield of crude oil on distillation.

The analysis of the gases evolved from the aeration channel of Sheffield activated sludge process showed 31.4 per cent CO_2, 23.4 per cent CH_4, 7.5 per cent H_2, 1.6 per cent O_2 and 3.6 per cent N. The author claims that a certain amount of anaerobic digestion takes place in the aeration chamber as well as in the settling tank. On dry distillation of surplus activated sludge without digestion the yield of crude oil obtained increased to 17.5 per cent. The specific gravity of this oil was 0.89. It was lighter in color and had a weaker aromatic odor than that obtained from digested sludge. Raw primary sludge gave only a yield of 11.5–12.0 per cent of crude oil on distillation. This material on distillation gave a brownish greasy tar prior to the fuel oil. The residue from distillation of the undigested fresh solids was like grain and differed greatly from the residue from activated sludge which had a hard plate-like appearance. The author favors the prior digestion of activated sludge, for the utilization of the gases produced in heating the retort, in spite of the higher yield of crude oil from the undigested activated sludge and does not consider favorably the distillation of fresh solids because of the difficulty of drying the solids. The author considers that the origin of crude oil especially from activated sludge is the microbial material in the plankton, algae and protozoa. The origin of crude oil from anaerobically digested sludge is attributed to the hydrocarbons formed by the action of anaerobic bacteria as well as to the bacteria themselves and the undecomposed residual fatty matters and proteins.

In an attempt to increase the quantity of fuel oil, mixtures of soy bean and starch were subjected to anaerobic digestion. The digestion of these materials was slow, requiring 200 days due to improper seeding and troubles due to the fluctuation in pH values. The yield of gas was 500 c.c. per gram of raw material added. The yield of

crude oil after the digestion of the soy beans and starch was 16 per cent of the weight of the digested residue. Soy beans without prior digestion gave 24.5 per cent fuel oil on dry distillation.

The gasoline fractions of the crude oil obtained from the distillation of various sewage sludges were as follows: primary settling tank sludge 22.8 per cent, raw activated sludge 22.6 per cent, activated sludge digested for 40 days 35.3 per cent. The gasoline fractions consisted of unsaturated hydrocarbons, aromatic hydrocarbons and paraffine and napthalene series of hydrocarbons. The amount of oxygen in the crude oils from digested sludge was much lower than in the undigested sludge indicating deoxygenation during digestion and giving an oil of high quality. There was no decrease of nitrogen and sulfur in the fuel oil derived from the digested solids.

In another experiment a mixture of bean curd (from soy beans) and potato starch and acid clay were digested anaerobically with ripe sludge for a period of 85 days, just before the production of combustible gas, in order to trap the substance for fuel oil. The undigested mixture gave a 22.5 per cent yield of crude oil, while after digestion 19.8 per cent of crude oil was obtained on distillation. A mixture of primary sludge and garbage in the ratio of 16:1 was digested for a period of 170 days. Digestion proceeded under acid condition due to the large amount of boiled rice and vegetables in the garbage. Only 244 c.c. of gas were produced per gram of volatile matter added. The yield of crude oil after distillation of the digested material was 11.0 per cent.

H. HEUKELEKIAN

CONTRIBUTION TO THE STUDY OF ACTIVATED SLUDGE

BY S. MIHAELOFF

J. Pharmacie et de Chemie, **30**, 13 (1939)

The rate of nitrification is accelerated during the activation of sewage so that the time required to oxidize 10 p.p.m. NH_3–N is reduced from 30 hours during the aeration of sewage to 1 to 2 hours after activation is complete. Bicarbonate is changed to calcium carbonate, which is precipitated. When the calcium carbonate content of sewage is high, nitrification is rapid. It is only when nitrification is established that activation is complete. The author contends that activation is the result of microbial action, which coagulates and oxidizes the organic matter in sewage. As evidence, he cites the constant presence of filamentous organisms in activated sludges derived from various sources such as sewage or dairy wastes and by different methods of activation. The higher the amount of microbial filaments, the more rapid is the rate of settling of sludge. The author re-confirms the accepted fact that nitrification is due to the action of two organisms, one of which acts only on ammonia and not on the nitrite and the other on nitrite, but not on the ammonia.

H. HEUKELEKIAN

ON THE USE OF DINITROPHENOLINDOPHENOL AS AN INDICATOR FOR THE DEMONSTRATION OF PUTRESCIBILITY OF SEWAGE

BY E. REMY

Arch. F. Hyg. Bakt., **119**, 10 (1937)

A comparison of the putrescibility test of polluted waters was made with methylene blue and dichlorphenolindophenol. One-half cubic centimeter of 0.05 per cent methylene blue was used in 49.5 c.c. of the water to be tested and 1 c.c. of 0.027 per cent so-

lution of dichlorphenolindophenol was added to 49 c.c. of water. Dichlorphenolindophenol was dissolved in a 10 per cent solution of 1/15 molar primary potassium phosphate and a 20 per cent solution of 1/15 molar secondary sodium phosphate. The dyes when diluted in the above quantities give the same color intensity. When these dyes were tested for decolorzation with pure organic substances, well waters and settled sewage, the decolorization proceeded faster with dichlorphenolindophenol than with methylene blue.

H. HEUKELEKIAN

BIRMINGHAM, TAME AND REA DISTRICT DRAINAGE BOARD

25th Annual Report. Year 1938–1939

This Board added 993 acres to its area in 1939. Of its sewage works site, 214.5 acres was sold. The annual cost, including interest and working expenses, was £227,650 ($910,600) in 1939–40, or 11 s. 11 d. ($2.44) per rated tenement (sewer connection) as against 11 s. 9 d. in 1938–39, and 11 s. 10 d. in 1937–38. The total cost per head, exclusive of pumping, was 42.6 d., or 73 cents. Capital expenditures in 1938–39 totaled £74,360 ($297,440).

At the Yardley Works, owing to the presence of iron salts and increased organic matter, the sewage is limed, then pre-aerated with surplus activated sludge and filter humus; settled; then treated in an activated sludge plant with aeration for one to two hours with reconditioned activated sludge. After settling, the effluent is distributed over trickling filters, and the effluent therefrom is settled. The aeration of sewage with lime and iron salts produced marked clarification. With the modified treatment, the trickling filter media has cleared up.

A study of the bacterial content in sewage and the sewage effluents shows the effect of industrial wastes in inhibiting bacterial action. An example of the results obtained at two plants is as follows:

Works	Colonies per C.C.		Coli aerog. per C.C.	Amm. N	P.P.M. Ox. Abs.	B.O.D.
	1 day 37° C.	3 days 22° C.				
Coleshill:						
Settled Sewage.....	210,000	960,000	50,000	44.1	63	145
Settled Effluent.....	2,000	220,000	3,000	41.2	17	12
Barston:						
Settled Sewage.....	120,000	680,000	50,000	25.7	29	125
Settled Effluent.....	2,000	20,000	800	0.4	7	7

LANGDON PEARSE

SYMPOSIUM ON INDUSTRIAL WASTES *

WATER POLLUTION

By Robert Spurr Weston

Ind. and Eng. Chemistry, **31**, 1311 (November, 1939)

Revival of industry has brought with it increased pressure from sanitary authorities, sportsmen's and nature lover's organizations and the general public for cleaner streams. Some states have passed drastic legislation prohibiting the discharge into streams of any waste that may prove injurious to public health or to animal or aquatic life or that may prevent the use of waters for domestic, industrial or recreational purpose. However, such legislation is not very conveniently enforced and a better approach is through cooperation between industry and the public authorities. The possibility of designating streams for particular uses is mentioned and streams are classified into (1) those which should be preserved in their natural condition and reserved for water supply; (2) those used for sewage disposed after treatment and for water supply after purification of the water; (3) those used for sewage disposal after such treatment of sewage or industrial wastes as is necessary to prevent nuisance.

Consideration must be given to the ability of a stream to handle the pollutional load discharged to it. This entails a study of the concentration of wastes which it is proposed to discharge into the streams and of methods of treating these wastes.

Population equivalents and oxygen demand of several types of wastes in Indianapolis have been reported by Calvert and Parks (*Sewage Wks. Jrnl.*, **6**, 1159).

In addition to their concentration as measured by B.O.D. and suspended matter certain wastes require consideration because of their individual characteristics. A few such wastes are (1) ligneous and resinous wastes from digestion of wood, paper stock, cotton cloth and vegetable fibers. Such wastes are highly concentrated and antiseptic and resist natural biological purification; (2) greasy wastes from wool scouring, tanning, meat packing; (3) nitrogenous wastes from animal industries; (4) carbonaceous wastes from starch, sugar, brewery, distillery and glucose factories; (5) soapy wastes from laundries and textile mills; (6) acid wastes from mines and metal works; (7) toxic gas house and coke works liquors; (8) oily wastes; (9) miscellaneous wastes which may contain arsenic, cyanide, dyes, etc.

In establishing standards for water polluted by industrial wastes it is customary to use such values as minimal dissolved oxygen, freedom from accumulated sludge deposits, or limiting bacterial content, all

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dependent upon the uses of the stream. It is generally agreed that the minimum dissolved oxygen content of a stream used for water supply shall be not less than 4 p.p.m. and that the D.O. of no stream should be permitted to fall below 2 p.p.m.

LEGAL ASPECTS OF THE INDUSTRIAL WASTES PROBLEM

By James A. Tobey

(Page 1320)

Legislation and judicial action alone cannot solve the problems created by industrial wastes. In addition to law the solution requires the use of such important elements as investigation and research, the application of new and established technical procedures, the education of industry and the mobilization of public opinion, and the provision for financial and economic aid where necessary.

Legislation, law enforcement and litigation, however, can be potent factors in helping to correct abuses due to waste products of necessary industries. The magnitude of the problem is indicated by the estimate that an expenditure on the part of American municipalities and industry of approximately 2 billion dollars a year over a period of 10 or 20 years would be necessary to abate the more objectionable pollution.

Whenever industrial wastes pollute the soil, atmosphere or water so as to cause harm or annoyance to individuals they constitute a nuisance. The corporation creating the nuisance is legally liable. A person who has been harmed or whose property has suffered damage may (1) bring suit for damages against the person or corporation responsible for the nuisance; (2) go into a court of equity and secure an injunction against the continuation of the nuisance; (3) take steps to abate the nuisance. The same principles of liability apply to municipalities or quasi-municipal corporations created by legislative enactment for specific purposes.

When industrial wastes become a public nuisance the court may order its abatement at the behest of the state or one of its political subdivisions. The person or corporation responsible for the nuisance may be liable to criminal prosecution and penalty for violation of a law prohibiting pollution by industrial wastes. When the nuisance places public health in immediate jeopardy, public authorities may order its immediate abatement.

The state may enact legislation to prohibit pollution of streams by industrial wastes. Usually such legislation is broad and enforcement is delegated to an appropriate administrative agency. The laws on the subject are deficient in many respects and vary considerably among the various states. Uniform and standard anti-pollution laws are very desirable. It is suggested that an advisory and coordinating agency be created in the Federal Government to investigate and advise the states how best to cope with the pollution problem.

UTILIZATION OF INDUSTRIAL WASTES

By H. E. Howe and F. J. Van Antwerpen

(Page 1311)

Industry has made significant progress in recovery of waste material for useful purposes. From sulfite liquors of pulp manufacture, alcohol, tanning compounds, adhesives, plastics, vanillin and other chemicals have been prepared. Calcium sulfite has been recovered and re-used and the liquor itself has been used in some instances to replace up to 40 per cent of the fatty acid in soap manufacture. From the black liquor of the alkaline process, activated carbon has been recovered. Quicklime is recovered and re-used from the sulfate process. White water has been "bottled up" and the fibres recovered by settling, filtration or flotation methods and returned to the process.

In addition to the usual products of destructive distillation, the wood industry and tan extract manufacturers have found it profitable to press sawdust into logs for fireplaces and to grade and briquette charcoal for fuel. The gases from the distillation processes have been collected and used as fuel at the plant.

Pickling liquor from iron and steel works is still a vexing problem. Some liquor has been used to recover copperas and "Ferron" has been prepared. However the volume of this waste is so large and commercial uses for the products recovered so small by comparison that little progress can be considered made in disposal of this waste.

By amalgamation, cyanidation and flotation methods, profitable amounts of gold have been recovered from the waste heaps of gold mining works. Cadmium is now a by-product of zinc smelting and selenium is recovered from the wastes of copper refineries. Tin is precipitated from spent weighting liquors and recovered for use again in textile weighting. Arsenic is recovered from gases of smelters. Mineral "wools," railroad ballast, sewage trickling filters, and agricultural phosphorus are obtained from blast furnace slag either by using the slag itself or by processing it.

Gases from petroleum cracking process have become the raw material for a long list of solvents and other chemicals. These same gases have been collected and bottled to be sold as fuel.

Carbon dioxide from fermentation processes has become an important source of dry ice.

Dusts collected by the Cottrell process have yielded products valuable in the manufacture of cement and abrasives for silver polishing.

Sewage sludge has yielded valuable fertilizer and gas for heating and power purposes.

Agricultural products once considered waste are being converted into valuable products. From surplus and skimmed milk which formerly found its way into the sewers or streams, casein and cattle feed is recovered. Other "waste" products are now yielding valuable building materials, plastics, chemicals and oils.

Packing plants now produce important medicinals from livers and glands. Eviscerated fish are converted into fish meal, glue and other products. Spent grain is recovered by distillers and processed for cattle feed. Ammonia and phenol are by-products of coking plants. Glycerol is a valued product of soap manufacture.

Other industries recover innumerable other products but much still remains to be done with wastes, many of which cause real nuisance in the air and streams of the country.

WASTE PROBLEMS IN THE PULP AND PAPER INDUSTRY

By Harvey J. Skinner

(Page 1331)

Waste sulfite liquors result from the cooking of wood with bisulfites of lime and magnesia. About half the original wood in the form of lignin and other non-cellulosic constituents together with some chemicals remain in the waste liquor. The most outstanding development in utilizing this waste and in reducing stream pollution is the Howard process developed by G. C. Howard of the Marathon Paper Co. Controlled precipitation with lime results first in the precipitation of calcium sulfite which is used in preparing new acid. Further treatment with lime results in the precipitation of the basic calcium salt of lignin sulfonic acid which can be used as fuel or as a raw material for preparation of a series of supplemental products. A third step, consisting of a short pressure cooking treatment, may be employed to remove the small amount of lignin remaining in the effluent. This permits a comparatively innocuous effluent to be discharged into the streams.

Other attempts to use sulfite liquors as a source of alcohol or by evaporation as a source of fuel have been too costly for practical use.

In soda and sulfate mills, wood is cooked either in caustic soda or in a mixture of caustic soda and sodium sulfate. The waste liquor containing half the original wood is evaporated and the organic residue burned leaving the original chemicals available for use. Approximately 85 to 90 per cent of the chemicals used are recovered.

The large amount of fiber, amounting to as much as 20 per cent of the weight of paper produced, which was formerly lost in the white water has been reduced by the use of save-alls and by a "bottling up" process to only one per cent in well operated plants. The result has been a double saving to the industry, through recovery of the fiber and re-use of water, and a lessening of the burden on the streams.

Waste problems are also introduced by strawboard manufacture and processes using rags and waste paper, for which satisfactory solution has yet to be found.

WASTE PROBLEMS IN THE FERMENTATION INDUSTRY

By C. S. Boruff

(Page 1335)

Brewers wastes are composed of the liquid pressed from wet grains, liquid from yeast recovery operations and wash waters from brew fermentation, storage and bottling departments. The combined waste has a population equivalent of about 15 to 25 persons per barrel and is too dilute to justify recovery and drying. It is disposed of through digestion with secondary aerobic stabilization.

Yeast wastes containing 3 per cent solids are most feasibly treated by digestion followed by trickling filters.

Still wastes from alcoholic fermentation of molasses contain about 5 per cent solids and have a 5-day B.O.D. of approximately 22,000. At the present time these wastes are concentrated in multiple-effect evaporators and burned. The ash is sold for its K_2O content, 33 per cent. Small quantities of these slops are concentrated and sold to poultry and stock feed processors as a source of vitamin G.

Distillery slops contain 4.75 to 6.0 per cent solids and have a B.O.D. concentration of 15,000 to 20,000 p.p.m. The thin slops are evaporated after centrifuging and filtering and the concentrated material containing 40 to 70 per cent solids returned to the dried spent grain and disposed of as stock feed.

The fermentation industries no longer contribute heavy pollution loads to streams and sewage plants. Bottling up processes have made it possible to recover much of this waste and that too weak to justify recovery is stabilized at the plant or in municipal treatment works.

INDUSTRIAL WASTES FROM EQUIPMENT MANUFACTURER'S VIEWPOINT

By C. L. Knowles

(Page 1338)

A billion dollars or more worth of equipment will be necessary to eliminate stream pollution caused by industry. The necessary equipment is already in use by sanitary and metallurgical engineers and it is necessary only to apply it intelligently to meet the needs of industrial waste treatment.

Several plans of classifying wastes have been proposed: (1) according to the nature of the waste (organic, toxic or inert); (2) according to source of difficulty (inert waste producing beds and bars which tend to block waterways; wastes which produce color or turbidity and are of-

fensive to city or state authorities; wastes which require B.O.D. correction, bacterial elimination, etc.); (3) according to type of treatment (physical, chemical, biological or any combination of them).

Each waste treatment problem must be treated as distinct and separate. Careful study must be given by competent sanitary, chemical and metallurgical engineers.

WASTES OF A CHEMICAL COMPANY

By I. F. Harlow

(Page 1346)

Wastes produced by the Dow Chemical Co. are divided into non-hazardous, brine, taste and odor producing, phenolic, and sediment bearing.

The non-hazardous wastes are mainly condenser waters from evaporation processes and seldom contain pollutional matter.

Brine wastes amounting to some 26,000 barrels are impounded and released during periods of high water flow into the Saginaw River.

Taste and odor producing wastes other than phenolic are impounded for cooling and clarification and re-used for quenching and gas scrubbing purposes.

Phenolic wastes are treated biologically on slag filters after clarification in a settling tank. The filter effluent is impounded to permit further biologic action. Wastes are reduced from as high as 30 p.p.m. to 0.05 p.p.m.

Wastes carrying sediment or wastes which may produce precipitates after mixing are impounded in shallow ponds where the solids settle out and oxygen is absorbed by the effluent before discharge.

BIOLOGICAL PROCESSES FOR TREATING WASTES

By A. M. Buswell

(Page 1349)

Biologic processes are fundamentally (1) aerobic or (2) anaerobic processes. The character of the solids and the gases produced are distinctly different in each case. Aerobic processes produce carbon dioxide and the hydrogen is converted to water. The solids are largely microbial protoplasm together with colloidal and suspended material caught on the biological jelly. The anaerobic process yields methane and carbon dioxide with a small amount of hydrogen. The resulting solids are a humus-like, practically inert material.

The choice between the two processes depends on the particular problem. The anaerobic process is cheaper per pound of organic matter stabilized. Anaerobic digestion of milk followed by treatment of the effluent on trickling filters was accomplished at a total cost of $8.70 per pound as compared with $116.80 on trickling filters alone.

Anaerobic processes are limited by the fact that (1) the quality of the effluent is not comparable to that produced by aerobic processes and (2) the cost of treating weak solutions is very high due to large tank space required.

Aerobic processes are carried out on trickling filters and in activated sludge tanks. The quality of the effluent is usually excellent. However, this process is unable to handle concentrated wastes without previous dilution of the raw waste with treated effluent. A combination of the anaerobic with the aerobic processes has been worked out for handling distillery wastes which shows promise of success.

Anaerobic digestion processes have been developed for treating coarse solids.

Phenolic wastes can be treated by either process unless they are introduced in excessive quantities.

TREATMENT OF LIQUID WASTES FROM THE TEXTILE INDUSTRY

By C. R. Hoover

(Page 1352)

If the natural-fiber textile industry is to avoid stringent regulation of all wastes discharged into streams, it must accept the fact that waste treatment is a legitimate part of the manufacturing process. The different means of treatment open to investigation are: (1) Dilution in the stream which present trends indicate must decrease in the future. (2) Equalization or mixing. This allows opportunity for dilution, regulation of flow, and mutual neutralization and precipitation reactions. This simple expedient often overcomes any opposition to acceptance of the waste into the municipal plant. (3) Storage. A large portion of the solids is removed and the liquor partially stabilized. Cooling is necessary prior to further treatment by chemical or biological processes. (4) Aeration. Emulsions are converted into removable scum. Aeration effects chemical oxidation. (5) Mechanical separation. This includes separation in tanks, centrifuges and other mechanical means. (6) Coagulation. Chemical precipitation of wastes indicates that ferric and ferrous sulfate, aluminum sulfate and aluminum sulfate in combination with ferric sulfate, chlorinated copperas and ferric chloride, activated carbon, sodium aluminate, clays and sodium silicate are effective in the order named. Disposal of sludge from coagulation proc-

esses is a major problem. (7) Biological action. The most effective manner of treating by biological action was by means of bio-aeration or trickling filters. Coke ballast showed a slight advantage over other filter media and also had the advantage that it could be disposed of by burning under the plant boiler.

Two typical layouts for textile waste treatment plants are shown.

WASTE PROBLEMS IN THE PETROLEUM INDUSTRY

By J. Bennett Hill

(Page 1361)

Oil in liquid refinery wastes is removed in a specially designed gravity separator after treatment of chemical wastes and breaking of permanent emulsions. Sulfuric acid is recovered from acid sludges for re-use in the refining processes and spent soda sludges are neutralized and then steamed or boiled to remove hydrogen sulfide and mercaptans. The final liquor is free from undesirable constituents and may be discharged with other refinery effluents.

No oily fractions offer a disposal problem since they have value as a fuel. Research is being directed, however, toward recovering more profitable substances from some of these waste materials.

WASTE PROBLEMS OF THE IRON AND STEEL INDUSTRY

By Willard W. Hodge

(Page 1364)

Liquid steel mill wastes which at times have found their way into the streams or the municipal treatment plant originate as flue dust, spent pickle liquor, oil and grease, ammonia liquors, and phenolic liquors.

Pollution by flue dust has been appreciably reduced by installation of mechanically cleaned settling tanks and rotary filters. The dust is sintered and returned to the furnace for recovery of its iron content.

Liquid wastes from the coking processes are treated for recovery of ammonium compounds. The tar produced is treated to produce a large number of chemical products and medicinals. Processes have been developed to remove taste producing phenols and phenolic compounds.

Disposal of waste pickle liquor offers a serious problem. It is estimated that from 500 to 800 million gallons of waste liquor is produced annually for which no adequate method of treatment has been found.

Efforts have been made to dispose of this waste by pumping (1) into deep wells, (2) limestone caves, (3) abandoned mines, (4) exhausted oil and gas sands, (5) evaporation ponds, (6) sand and gravel sumps, (7) sewers discharging into streams or other body of water. The waste has also been partially treated before discharge into streams by (1) treating with enough lime to neutralize the acid, (2) with excess lime to precipitate the iron as hydroxide, (3) by other methods of neutralization with limestone, marl, scrap iron, etc.

A large number of processes have also been developed and patented for recovering useful products from pickle liquor. They may be classified as follows: (1) manufacture of copperas ($FeSO_4.7H_2O$) or siderotilate ($FeSO_4.5H_2O$), (2) copperas and free sulfuric acid, (3) ferrous sulfate monohydrate and free sulfuric acid, (4) electrolytic iron and sulfuric acid, (5) iron oxide for paint pigment or polishing rouge, (6) ferric sulfate and sulfuric acid, (7) sulfuric acid and iron oxide, (8) "Ferron," (9) ammonium sulfate and iron oxide, sulfide or carbonate, (10) miscellaneous processes for making other inorganic compounds.

A discussion of each of the above processes with principal reactions is given. Recovery processes have been retarded by high costs of installation, equipment, maintenance and operation due to the corrosive nature of the material. Lack of anything like adequate markets for the products produced also tends to retard installation of recovery processes.

E. HURWITZ

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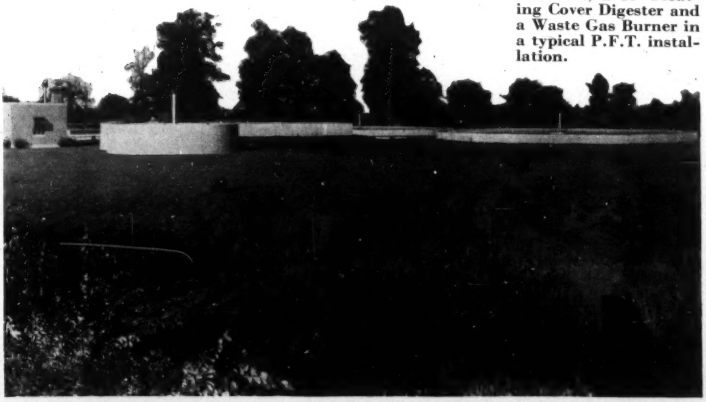

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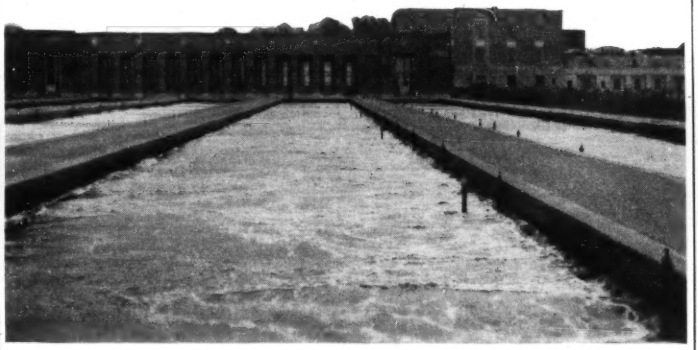

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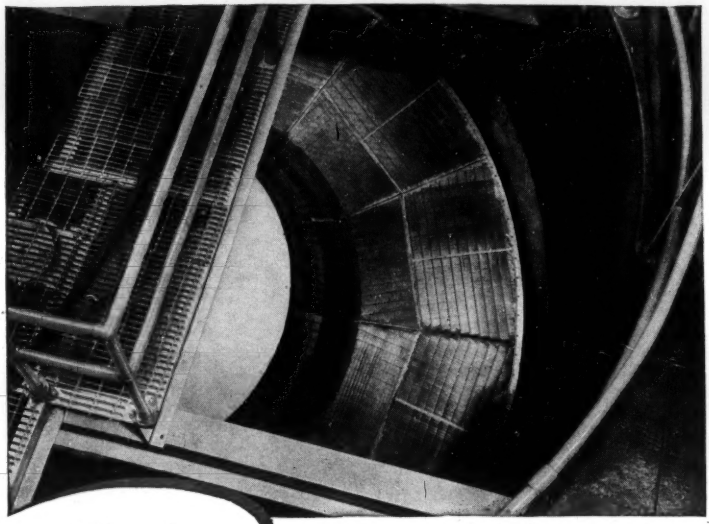

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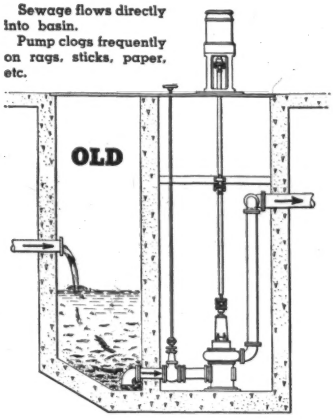

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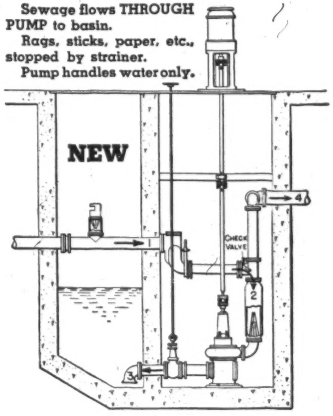

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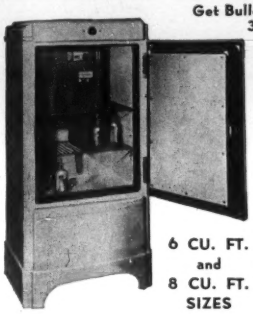

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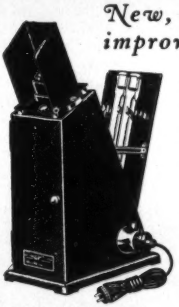

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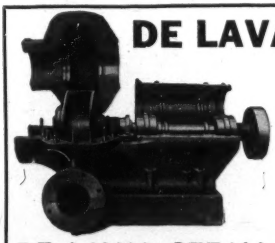

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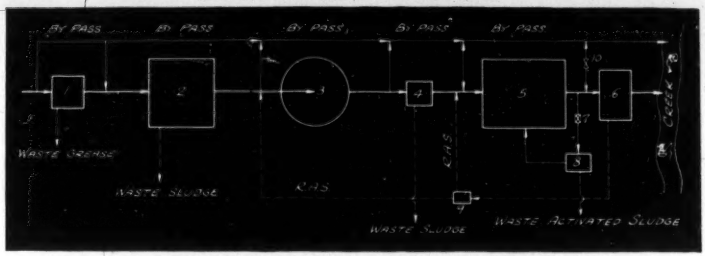

EXPLANATION AND DESIGN FACTORS

The use of this two stage plan allows for ease of treatment of strong, septic, or difficult industrial wastes.

The plan has all of the advantages of the shock capacity of a trickling filter together with the accelerated rate of complete treatment of activated sludge.

1. Grease Flotation—Pre-aeration Unit
   30–45 min. retention.
2. Primary Settling Tank
   90 min. retention following pre-aeration, otherwise use 60 min.
3. Roughing Filter
   20 to 30 cu. ft. media/No. BOD applied/da. Use stone passing 3″ to 4″ sieve. Bed 3′ to 4′ deep.
4. Intermediate Settling
   10 to 15 min. retention—maximum hourly flow.
5. Aeration Tanks
   200 to 240 gal. tank capacity per pound of BOD applied and not less than 1 hr. @ maximum hourly flow.
6. Final Settling Tank
   90 min. @ maximum hourly flow—Recommend 9′ water depth.
7. Sluice Gate to Regulate Waste Activated Sludge.
8. Waste Activated Sludge Tank.
9. Return Activated Sludge Diversion Chamber.
10. Valve for By-Passing Activated Sludge to Effluent.

Design Criteria:

Thru Pre-aeration—Grease Flotation and Primary Settling—Assume 40–50% reduction organic load.

Thru Plain Primary Sedimentation only—Assume 25–30% reduction organic load.

Thru Roughing Filter (@ 30 cu. ft. of stone/No. of BOD)—Assume 60% reduction applied organic load.

NOTE: The design factors shown above are only descriptive. For absolute design factors apply to the Sanitary Division and do not under any circumstances apply these sheets without company authorization.

THE AMERICAN WELL WORKS INC.
MANUFACTURERS
PUMPING & SANITATION EQUIPMENT
AURORA - ILL.

TC
TENNESSEE CORPORATION

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FERRIC SULPHATE

FINEST QUALITY

T.C.'s Coagulant "Cost Cutter"

A Coagulant for all types of water treatment and sewage. Also adaptable for waste water treatment.

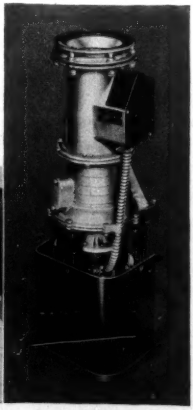
Send for literature, and sample to test in your plant

TENNESSEE CORPORATION

ATLANTA, GA. **LOCKLAND, OHIO**

THE MODERN WAY TO DISPOSE OF FOOD WASTES

G-E DISPOSALL

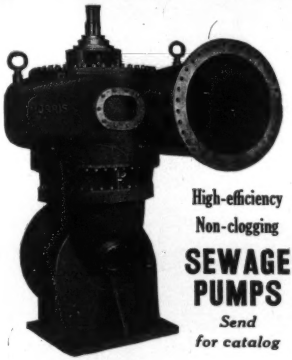


Easily installed in practically any kitchen sink, the General Electric Disposall quickly reduces fresh food wastes to a fine pulp and washes it away like water through the community sewage system. Eliminates the unsanitary, unsightly garbage can and its attendant problems.

The effect of pulped food wastes on sewage treatment systems is fully covered in authoritative reports by well-known sanitation engineers. Write for complete information to General Electric Company, Appliance and Merchandise Dept. NR-0393, Bridgeport, Connecticut.

GENERAL ELECTRIC

MORRIS
CENTRIFUGAL PUMPS



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Non-clogging
SEWAGE
PUMPS
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BALDWINSVILLE, N.Y.

YEOMANS SIMPLEX
Mechanical Aerator

ITS S-L-O-W SPEED MEANS LONG LIFE

Yeomans-Simplex Aerator achieves high purification at low operating cost, because the sewage is lifted only a few inches. Maintenance costs, too, are low because the cone revolves at only 40-58 rpm and because bearings are above the liquor surface; many of these machines have been operating for as long as 8 years with no expense at all for repairs or service. Don't you think it's worth investigating? Write today for complete details.

Pumps, Distributors, Clarifiers, Digesters, Aerators
YEOMANS BROTHERS COMPANY
1411 N. Dayton St. Chicago, Illinois

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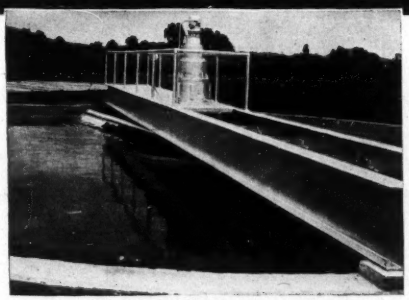


● INFILCO CLARIFIERS are well designed to offer the maximum in efficient performance, and are substantially constructed of high grade materials to render a long, trouble-free service life.

Write for information on the advantages of Infilco Clarifiers for application in the sewage treatment field.

INTERNATIONAL FILTER CO., 325 W. 25TH PLACE, CHICAGO, ILL.
EQUIPMENT FOR CHEMICAL, BIOLOGICAL AND MECHANICAL TREATMENT OF SEWAGE

THE lawbreaker with a revolver who runs rampant in a community is quickly apprehended and brought to justice. Diseases, water borne or carried by insects, are another matter. They work quietly and are undetected until an epidemic strikes. Even communities with highest sanitary ratings must continually be on guard.

When you specify material we ask you to consider the use of vitrified clay pipe exclusively. The sewer that fails through disintegration and from other causes—which often destroy substitute materials—is the community's most dangerous enemy. Typhoid and many other diseases need only a break in a sanitary sewer to spread disease through the whole community in the drinking water.

A sewer system is no better than the materials that go into it. Vitrified pipe has served many cities in the South for over half a century—some for over a century. To duplicate this service specify vitrified pipe.

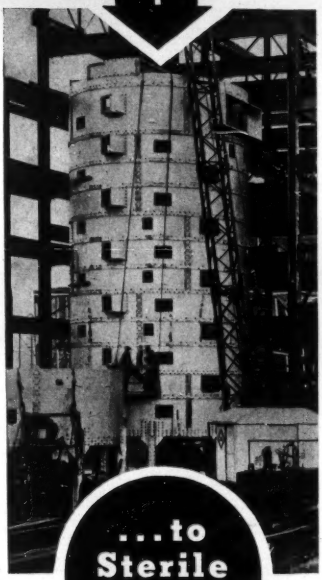
SOUTHERN VITRIFIED PIPE ASSOCIATION

628 SYCAMORE STREET, CINCINNATI, OHIO

THE SOUTHERN VITRIFIED PIPE ASSOCIATION IS ALWAYS PLEASED TO COOPERATE WITH THE ENGINEERING PROFESSION. CALL ON IT OR ITS MEMBERS FOR ANY GENERAL OR SPECIFIC SERVICE.

From Offensive Sewage Sludge...

Annually more than a million tons of sewage sludge drop from one NICHOLS HERRESHOFF HEARTH to another, discharging from the bottom hearth as sterile ash



...to Sterile Ash

Thirty-four United States communities are now disposing of their dangerous and offensive sewage solids in this sanitary manner—without smoke or offensive odors—and at a remarkably low cost per ton of sludge incinerated.

Units now operating range in size from 4 tons to 1400 tons daily capacity.

Any community interested in the sanitary disposal of municipal solid wastes—including sewage sludge, screenings, grit, garbage or rubbish should write "Incineration Headquarters" for information and data.

NICHOLS

ENGINEERING & NERCO RESEARCH CORP.

60 WALL TOWER NEW YORK, N. Y.

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MAYBE you've never been in the same predicament as our young friend above but, if you've ever operated a piece of mechanical apparatus, you've doubtless felt just as helpless while trying to make some adjustment or repair.

With a W&T Visible Vacuum Chlorinator you don't have to run around corners or tie your back in kinks to reach some hidden part. It's all out in the open, with operation as visible as the view of the street from your own front porch and every part easily accessible without muscular contortion or mental strain. Lift the bell jar and the complete mechanism is ready to your hand; remove the full height side panels and all of the connecting pipe and hose lines are within easy reach.

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